S·A·E JOURNAL

PUBLISHED BY THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

William B. Stout, President — David Beecroft, Treasurer

John A. C. Warner, Secretary and General Manager

Norman G. Shidle, Executive Editor

Vol. 37 — NOVEMBER, 1935 — No. 5

CONTENTS

Transactions Section Begins

Refinements and Super-Styling in the 1936 Models—Austin M. Wolf . . . 385

Evaluation of Variables Influencing Air Cooling of Engines—Kenneth Campbell 401

An Analysis of Critical Stresses in Aircraft-Engine Parts—C. Fayette Taylor 412

Design and Maintenance Problems on Heavy-Duty Brakes—Norman Leeds, Jr. 419

Application of Induction Heating in Automotive Production—E. L. Bailey 422

Transactions Section Ends

Loading and Overloading Topics at Transportation Meeting 13

Transmissions and Research Share Spotlight at Tractor Meeting 15

Tractor Activity Nominates Vice-President for 1936 16

Behind the Scenes With the Committees 19

S. A. E. Pacific Regional Meeting . . . 21

S. A. E. Annual Dinner—Nov. 4 22

News of the Society 24

Membership Activities 27

What Members Are Doing 28

New Members Qualified 30

Applications Received 30

Papers Available in Mimeographed Form 31

Meetings Calendar 32

Notes and Reviews 34

Publication Office, 56th and Chestnut Sts., Philadelphia, Pa.; Editorial and Advertising Departments at the headquarters of the Society, 29 West 39th St., New York, N. Y. Western Advertising Office, Room 2-136 General Motors Bldg., Detroit, Mich.

The Society is not responsible for statements or opinions advanced in papers or discussions at its meetings or in articles in the JOURNAL.

Steering Needs More Than Ease for *Safety at High Speeds*

DEFINITE STABILITY must be present for complete steering safety at high speeds. Ease alone is not enough. Ross Steering, through its exclusive cam and lever design, combines the essential steadiness without sacrificing the desirable easy wheel-turn. Thus it gives utmost satisfaction at all speeds.

ROSS GEAR AND TOOL COMPANY • LAFAYETTE, INDIANA

ROSS CAM & LEVER STEERING

Refinements and Super-Styling In the 1936 Models

By Austin M. Wolf
Consulting Engineer

UNCEASING activity over the last ten months has culminated in a voluminous amount of detail design. A considerable number of major developments have been put into production and an unusual excellence of styling is to be found everywhere as well as increased safety measures.

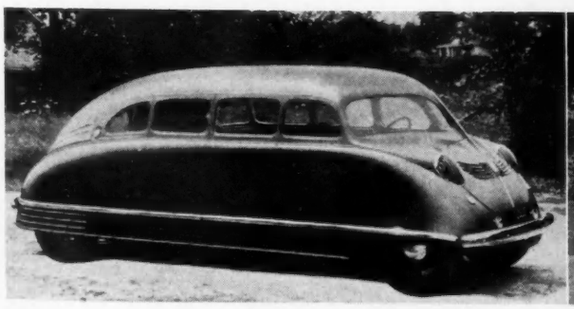
Outstanding developments are Buick's and Chevrolet's valve gear temperature control, the Chevrolet combustion chamber as affecting brake mean effective pressure, packless water pumps, the Buick choke adjustment for varying fuel volatility, the Studebaker "hill-holder," the Hudson front-axle radius rods, the Goodyear Lifeguard tube, the Chevrolet box-type frame rail, the Cadillac steering column with universal joints, more spacious and beautiful bodies, and the Hudson dustless ventilating system. Decided trends to be noted are the approach toward "square" engines, the use of aluminum pistons, die-cast radiator grilles, hydraulic brakes, the practical extinction of wire wheels, front-side sway eliminators and greater rigidity in frames, particularly at the x-member. Special mention should be made of the Cadillac connecting-rod big end, the Nash "400" manifolding and the unusual Scarab and Cord features.

Car ability has been increased and top speed possibilities of 90 m.p.h. are quite prevalent. A reduction in weight has been worked out on many cars which, in conjunction with increased power output, results in superior performance. Simplification in the number of models or the use of the same units in several models simplifies the production problem. Buick, for instance, has two engines in place of four, the rear springs have been reduced from 16 types to 7 and the bodies from 25 to 14. Greater engineering coherence is to be noted throughout the General Motors line and their method of trying out a new design is novel. The LaSalle 35-50 paved the way for present Cadillac design, as did the Buick "40" for the other series. The Auburn supercharged model has been extended to the convertible and five other models. A noticeable trend is the increased purchasing of parts from the parts makers.

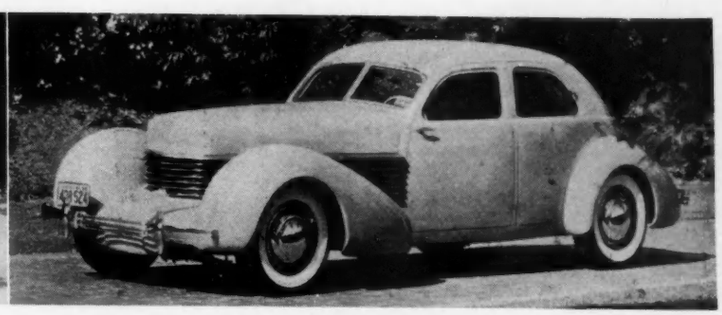
In this day of conservative engineering, it is refreshing to check over two new conceptions bristling with advanced design. The Scarab and Cord are pioneering many new features which are certain to have repercussions throughout the industry. The rear-driven Scarab combines a body and chassis in one unit designed along the lines of an airplane fuselage, weighing less than 3000 lbs. and seating seven passengers in an unconventional arrangement. Space utilization is remarkable. The suspension is along the lines of airplane "oleos" and worked out so that the center of gravity is below the supporting points, resulting in unparalleled stability on curves into which it automatically banks. Electric push buttons open the doors and louvres in lower body skirting permit ventilation of the rear wheel brakes. A large grille is incorporated in the center of the rear body panel, the headlights are semi-enclosed and the V windshield is exceptionally wide.

While following more conventional lines, the front-driven Cord has also aimed to remove all protuberances and in this case the radiator, spare tire and headlights (when not in use) are completely hidden. In order to maintain a weight distribution of 55 per cent on the front wheels, the transmission is

[This paper presented at the Regional Transportation and Maintenance Meeting, Newark, N. J., sponsored by the Metropolitan Section of the Society.]



Rear-Engined, Rear-Driven Scarab



Front-Driven Cord

located ahead of the differential. The entire powerplant is easily removed. The car weighs about 3500 lb., has 125 in. wheelbase and a top speed of 95 m.p.h. With its short turning radius it can be turned around in a 20½ ft. width.

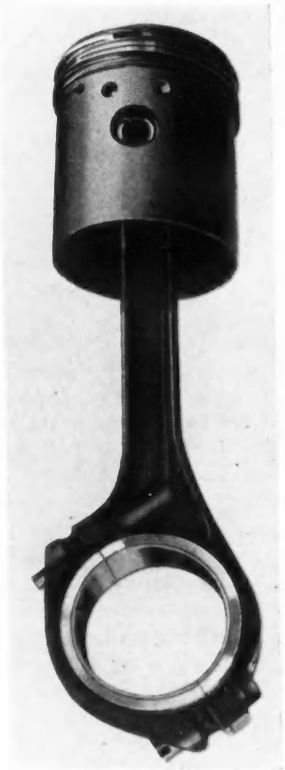
Engines

The trend toward the "square" engine by General Motors which was initiated in the original Pontiac, is to be found in the new Buick and Cadillac designs. Piston speeds are reduced for a given engine speed in revolutions per minute and the latter are furthermore reduced by the faster axle ratios used. The large Buick engine is 3 7/16 in. x 4 5/16 in. as contrasted to the previous "90" with 3 5/16 in. x 5 in. The piston travel per mile at 60 m.p.h. is 2185 ft. as against 2490. Last year's Cadillac-8 had a 3⅜ in. x 4 15/16 in. bore and stroke, whereas the present "60" is 3⅜ in. x 4½ in. and a ⅛-in. larger bore in the "70" and "75." At 3000 r.p.m., the piston speed is 2250 ft. per min. as against last year's 2470. With the rear axle stepped up from 4.6 to 4.1 the relative piston travel in feet per mile is 2190 on the present "60," as against 2575 for last year's model 10 and 20. The specific output of 0.40 hp. per cu. in. compares with 0.36 on the 355-D engine.

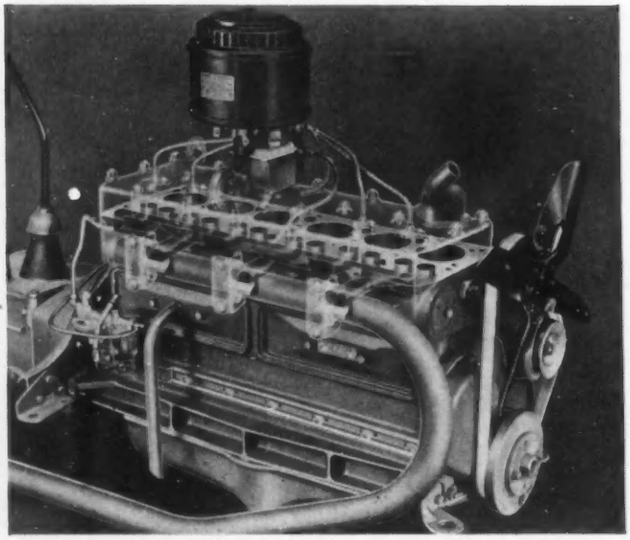
The Studebaker Dictator has an entirely new six-cylinder engine, 3¼ in. x 4⅜ in., 217.8 cu. in. displacement and developing 90 hp. at 3400 r.p.m. The President now develops 115 hp. at 3600. The Cord has an eight-cylinder 90 deg. V Lycoming engine, 3½ in. x 3¾ in., 288.6 cu. in., which, because of its compactness, enables the body to be brought further forward as contrasted with an "in-line" engine. It weighs 566 lb. dry, including fan, generator and accessories, and develops 125 hp. at 3500 r.p.m. One horsepower is derived from each 2.31 cu. in. displacement and the engine weighs 1.96 lb. per cu. in. and 4.53 lb. per horsepower. Rifle-drilled rods, piston-pin bushings of hardened aluminum-bronze, three 2½-in. main bearings and aluminum heads are used. Compression ratio is 6.5 to 1 and the valves are almost horizontal, inclining upwardly at about 10 deg. The Autolite generator is belt-driven from the rear end of the camshaft and the fan and water pump unit is driven from another belt at the forward end. One of the water outlets from the engine and the breather pipe in the top of the valve alley cover have extensions to the rear to provide filler openings for water and oil under the right cowl "ventilator" opening.

The Packard "120" stroke has been increased to 4¼ in., the displacement from 257 cu. in. to 282 and the horsepower from 110 to 120 at 3800. The bore of the Pontiac-8 has been increased 1/16 in., raising the displacement from 223.4 cu. in. to 232.

Terraplane Six, 3 in. x 5 in., with a 6 to 1 compression ratio and cast-iron head, develops 88 hp. at 3800. Stepping up the ratio to 6.25 to 1, this engine in the Hudson Six develops 93 hp. at the same speed. An optional aluminum head with 7 to 1 ratio brings the output to 100 hp. The Hudson Eight 3 in. x 4¼ in. and 6 to 1 ratio develops 113 hp., which is stepped up to 124 with the optional aluminum head with 7 to 1 ratio. Chevrolet has done a remarkably fine job in developing 114 lb. b.m.e.p. between 900 and 2000 r.p.m. corresponding to a torque of 156 lb-ft. 79 hp. is developed at 3200, which is a sacrifice of 1 hp. over last year's output, but with better performance below the peak. The compression ratio has been stepped up from 5.6 to 6.1. Plymouth leads the cast-iron heads with a 6.7 to 1 ratio, developing 82 hp. at 3600. The highest ratio used with aluminum heads is 7.45 to 1, where it is optional on the Airflow Chrysler Imperial. The 130 hp. at 3400 with cast-iron head is stepped up to 138. The Oldsmobile engines retain the same compression ratios as last year, even though aluminum pistons are used.



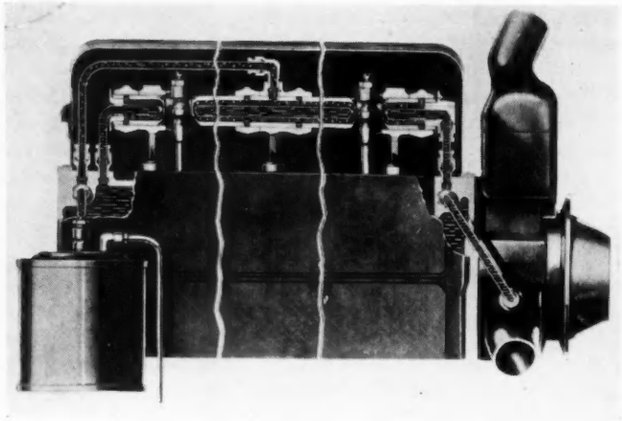
Cadillac Connecting Rod



Nash "400" Engine with No External Manifolds

Cylinders and Valve Gear

Chevrolet has reshaped the combustion chamber to attain smoothness with the higher compression in accordance with



Buick Valve Gear Temperature Control

the flame control theories expounded at the S.A.E. 1935 Annual Meeting. The wall thickness around the valves is now more uniform. The Pontiac-6 combustion chamber is now provided with the depressed bosses above the exhaust valves as incorporated in the Pontiac-8. The Cadillac-8s have block casting of the cylinders and the upper half of the crankcase. The engine is shorter, measuring only 20 in. over the blocks and is considerably more rigid. The wall at the top of the cylinder block at the surface where the head is attached is heavily reinforced to avoid distortion. The thickness of the wall around the valve ports of the combustion chamber is ⅜ in. and the lower wall of the cylinder head is also thicker. A through boss extends from the top wall of each cylinder block to the crankcase, thus tying the structure rigidly together. Bores are triple-honed and held to within 1/10,000 in. Micromatic finishing is increasingly popular.

The Oldsmobile exhaust valve seats have been changed from 30 deg. to 45 deg. to reduce the possibility of burning. The Permite Diachrome valve is made from high chromium nickel austenitic steel on the head and upper stem in view of its high resistance to the corrosive effects of the general run of fuels and is welded to an S.A.E. 3140 lower stem which is suitably hardened to give good stem and key seat wear. It is being used by Graham, Hupmobile, Studebaker, Nash and Packard "120."

In view of the creditable performance of the Cord Lycoming engine, some of its details would not be remiss. The Silchrome exhaust valve has a 45 deg. seat, 1⅜ in. port diameter, opens 50 deg. before bottom center and closes 5 deg. after top center. The nickel-steel inlet has a 30 deg. seat, 1½ in. port, opens 7½ deg. after top center and closes 37½ deg. after bottom center. Both valves have a 7/32 in. lift and 45 lb. springs hold them on their seats. The Hudson and Terraplane valve stems have been increased from 5/16 in. to ⅜ in. On the large Buick engine a water tube passes through the center of the rocker arm bearing shaft through which cooling water is drawn from the rear of the head jacket and discharges into the pump inlet. The valve gear is rapidly warmed up, particularly the push rods due to the oil running down over them and the time for them to reach their operating temperature is reduced. In the summer the oil is cooled and the increase in viscosity maintains valve clearances. Dynamometer tests made in air temperatures of from 5 to 8 deg. above zero show that 10 min. is required for the oil going to the rocker arms to warm up completely to a temperature of 110 deg. On the 1935 Buick "60" using the oil temperature regulator, 22 min. is required to accomplish the same result. Road tests at the temperatures mentioned above indicated that 10 min. is required at 25 m.p.h. before the valves are quiet. On the 1935 engine it took 18 min. The oil supply line to the rocker shaft on the Chevrolet runs through the cylinder block, where it is surrounded by water for the same objective as in the case of Buick. In comparative tests after one minute of operation at 20 m.p.h. the oil going to the push rods is 20 deg. hotter in the new engine than in last year's. After 3 min. the oil is 22 deg. hotter and then cools off to the same temperature after 16 min. At the end of 50 min. running the oil is 40 deg. cooler than in the previous engine. These tests are based on an atmospheric temperature of 50 deg. with a car speed of 20 m.p.h. for the first 12 min., 30 m.p.h. for the next 15 min., 50 m.p.h. for 12¼ min. and 70 m.p.h. for the remaining 10¾ min. The lower end of the Chevrolet exhaust valve guide is now counterbored ¼ in. deep.

Buick is now using front end timing chains which appeared first on the original "40." They are all Link Belt, ½ in. pitch, 1 in. wide on the "40" and 1¼ in. on the large engine. The chain has no adjustment and runs over a steel crankshaft sprocket and a semi-steel camshaft sprocket. Link Belt chains are also used on Willys, Graham, Stutz and Duesenberg, the latter two having automatic adjustment. The camshaft in the Caddillac-8s is now solid instead of drilled.

The Wilcox-Rich barrel-type tappet with flat base is used by Buick in place of the previous roller type. The apertures in the side walls lighten the tappet approximately 20 per cent over the solid wall type. Furthermore, the lower openings act as oil-draining passages, so that the tappet will not fill up and increase its weight. Being made in a permanent mold, the side walls as well as the face are all chilled white iron. The portion of the mold that forms the openings is a pad which holds and locates the inside core properly centered within a few thousandths. Studebaker has changed over to a solid barrel-type tappet in place of the previous mushroom. Cadillac is now equipped with the Wilcox-Rich hydraulic lash adjusters. Oil is fed under pressure to four cavities in the block, each one supplying four tappets. The flat base of the tappet calls for changed cam contours and the timing is different. The inlet valve opens on top dead center, closes 42 deg. after bottom center, and the exhaust opens 52 deg. before bottom center and closes 10 deg. after top center. The inlet valve diameter has been increased to 1⅞ in. The exhaust is 1⅝ in. and both have a 45 deg. seat angle.

Reciprocating Parts and Crankcase

The increase in car weights or the desire to obtain better performance characteristics has brought the aluminum piston into its own. At the present time the Chevrolet and Pontiac are the only cars using cast iron. Buick and Oldsmobile have changed over to aluminum pistons with anodic surface treatment. Oldsmobile permits cars to be driven 50 m.p.h. during the breaking-in period. Buick, likewise, permits high speed. Both these pistons are of the T-slot type. The Buick wristpin oscillates in the piston boss. An oil duct leads to each boss, being drilled back of the bottom ring groove. The Oldsmobile piston is cam-turned and finished with a diamond tool. It has a wide top land which protects the ring from the hot gases of combustion and a groove in the land acts as a heat dam which tends to either restrict the flow of heat to the ring section or deflects it toward the middle of the piston.

The thin-walled nickel iron Pontiac pistons have 3/16 in. shorter skirts on the 8 and ⅛ in. on the 6.

Buick performance has naturally been increased by the change from a 5.43 lb. piston and connecting rod assembly to one weighing 3.86, these comparisons being between the present large engine and the previous "90." The connecting-rod bearing load at 70 m.p.h. has been reduced from 2040 lb. to 1440 lb.

The fitting and design of rings into the short stroke engine, other conditions being equal, is a much easier task and the trend toward "square" engines will improve ring performance. Oldsmobile is now using four rings, two ⅛ in. compression and two 3/16 in. oil control. The Pedrick S.C. compression ring used in the Pontiac and the Canadian Pontiac and Chevrolet engines has a small circumferential groove in the lower face of the ring, below which is a relief undercut back from the cylinder wall so that oil may enter and leave the groove. Both the groove and undercut terminate adjacent to the gap. The design aims to improve oil consumption. As the cross-section of the ring is not symmetrical, its "collapsing" into the cylinder on the down stroke produces a slight twist or dish bringing the upper edge of the groove into sharp contact with the cylinder wall. The concentration of pressure on this line contact gives an extremely effective wiping action. The oil instead of being dumped at the bottom of the stroke is carried back up by the undercut which distributes it over the surface of the wall.

Angle split connecting-rods are used in the Cadillac-8s, permitting the pistons to be removed from the top. The caps are located by integral tongues that fit in grooves in the rod which is now of shorter length. The rifle-drilled oil passage is retained at the junction of the web and flange. The Packard "120" rods have been shortened 3/16 in. and the big end stiffened to provide a better support for the bearings. The LaSalle rods are held to within 1/32 oz. by removing metal from a forged-on boss. The assembly of rod, piston and wrist-pin is kept to within 1/64 oz. by selecting one of thirteen lock screws which have different head heights so that one screw is 1/64 oz. more than the one preceding it in the series.

The Cadillac-8 crankshafts have integral counterweights on the first, third, fourth and sixth cheek, while the second and fifth weights are secured by cap screws and piloted by dowels. The main and crankpin bearings are 2½ in. diameter, as compared to 2⅜ in. on the 355-D engine, resulting in a ¼-in. overlap of the pin and main journals. The main bearing caps are cast iron to correspond with the crankcase and are retained by cap screws instead of studs. Each pair of plate spring assemblies in the Buick vibration damper is now nested between two end aligning strips, the entire assembly being received by four notches in each hole of the inertia member. Cadmium-silver-copper bearings are being used in the Hercules Diesels to permit closer fitting. It is also used for the Ford full-floating connecting-rod bearings.

Ventilating air enters the oil filler at the left-hand side of Cadillac-8 engines since the cooling fan builds up an underhood pressure on that side. After passing through the crankcase it leaves by way of two openings in the valve compartment cover, one passing to the intake manifold and the other to the air silencer elbow above the carburetor, and all fumes pass through the engine. The two outlets discharge into the intake system after and before the carburetor, giving a high flow of ventilating air at low engine speeds when the manifold vacuum is maximum and at high engine speeds when the velocity of the air rushing into the carburetor provides suction. The Chevrolet crankcase is fitted with a baffle at the breather opening to prevent loss of vapor at high speeds. Pontiac accomplished this by a trap which turns the ventilating current through an angle of 180 deg., thereby separating out the oil.

The Harrison oil temperature regulators have been left off the Buick this year, while Chevrolet provides such a unit as optional equipment, being inserted in the line between the radiator outlet and the pump inlet. Studebaker provides baffle plates in the sump to insure an ample supply of oil around the pump at all times. A screened float oil-pump intake in the form of an inverted cup is located at the rear of the Cadillac-8 engines, being bolted to a flat surface at the left side of the rear main bearing. The oil-pressure regulator is built into the pump body and is of the piston type. Overflow is bypassed back to the pump inlet. Aside from four short pipes leading to the hydraulic lash adjusters, the only piping in the Cadillac lubricating system is the oil gage line. The Chevrolet oil-pressure pipes, formerly pressed in the block to convey oil to the three main bearings, are now replaced by a drilled passageway in the crankcase. Oldsmobile has added an oil spurt hole in the connecting-rod big end to spray oil onto the cylinder wall just prior to the piston reaching top center. Oil is discharged through holes in the Cadillac-8 connecting-rod big ends so that the rods in the left bank lubricate the right block, while the right hand rods lubricate the left bores. Oil-pressure in the Pontiac has been increased from 28 to 45 lb. and the crankshaft rear oil seal improved.

Cooling System

The provision of full length water jackets is increasing, now being incorporated in the Chevrolet, Pontiac, Studebaker and Chrysler-6 (which is also used in the DeSoto Airflow) engines. There is further use of the water distributing tube to cool the exhaust valve seats. Buick provides a deeper jacket. Chevrolet claims a 50 deg. cooler lubricating oil temperature than formerly, which ran 125 deg. hotter than the cooling water. The Chevrolet water capacity has been increased from 11 to 15 qt. Plymouth claims a maximum oil temperature of 217 deg. regardless of driving conditions, which is 50 deg. to 75 deg. cooler than the engine of two years ago, which did not have full length jackets. The cumbersome packing nut on water pumps is on the way out. In the Nash "400" a bakelite ring encompasses and is pinned to the pump shaft and seated against the inner surface of the cover plate. The ring is held in this position by a synthetic rubber sleeve which surrounds the shaft between the impeller and the ring, being under constant compression. It is impervious to alcohol, oil or other substances which might be in the cooling water. In the Hudson and Terraplane pumps a graphite-impregnated cork washer surrounds the shaft and has a stainless steel washer on each side of it. A coil spring presses against one of the steel washers, causing the cork to seal the pump, which is now of the pressure instead of the suction type, for more effective flow to the car heater when one is installed. Schwitzer-Cummins utilizes a spring-loaded carbon disc, the sealing side of which is lapped convexly on a very large radius and rubs against the lapped surface of the pump body. A synthetic rubber member makes a seal between the carbon disc and the shaft. The whole assembly is mounted inside of the impeller hub and held there by a pressed-on cup. The carbon disc has four keys which fit into slots in the hub. In the Cadillac-8 engines the belt-driven pump is mounted at the front cylinder of the right block. A spring-loaded chevron water-pump packing is used. A cored passage delivers half

of the water to the left-hand block, reducing the hose connections from six to three.

With the higher speeds and loads on pump shafts, ball-bearings have come into the foreground as shaft mountings. Permanently lubricated bearings are used by Cadillac. In the Schwitzer-Cummins pumps two single felt-seal bearings are used and the space between them is filled with ball-bearing grease. Buick uses the New Departure sealed outer bearing at the front end of the pump fan-unit on the larger engine and a bypass pressure relief valve is located below the thermostat.

A quieter cooling fan on the Cadillac-8s is obtained by using a smaller diameter fan driven at slightly higher speed. The fan rotates on two permanently sealed ball bearings and with the crankshaft pulley and water pump completes the triangular drive units. The generator is driven from a second groove in the crankshaft pulley. The Ford truck is now equipped with a four-blade 19-in. fan located closer to and parallel with the radiator core. It runs at engine speed instead of 1.28 faster and still has greater air-flow.

With the advent of the steel body with steel top, a new acoustical problem has presented itself. The confined air in the body has a certain sensitivity to noises of fan, intake silencer, muffler, etc. The body appears to amplify these sounds to a marked degree if these stray sounds are frequencies in the neighborhood of the resonant frequency of the air in the body. This phenomena has manifested itself to a marked degree in some of the 1935 cars. The fan required to eliminate part of this trouble, due to the fan itself, is an entirely new arrangement of blades so arranged that the generated frequencies are not in the acoustic amplification range of the body air volume. At the present time it does not seem that this type of blade arrangement will be necessary for use with all cars with steel tops. However, to combat this situation, Hayes Industries have evolved fans with radical changes in blade spacing. One such example is an asymmetrical four-bladed balanced unit in which the spacings are all unequal.

The Hudson radiator is mounted on the frame at the bottom center without a tie rod between the fenders and the radiator shell. A more efficient core in the Packard "120" results in a 20 per cent increase in cooling at low speeds. A 10 per cent increase in heat dissipation is obtained in the Cadillac-8 cores by increasing the water tube spacing to ⅝ in. and increasing the copper surface exposed to the cooling air. The new radiator flows more air so that the under-hood temperature is decreased by about 10 deg. Water passages are not so easily stopped up, being more than twice as wide and with smooth walls. A rod can be passed down through the tubes if blocked.

A pressure vent valve in the filler cap of the Cadillac-8 and 12 prevents the cooling fluid reaching the overflow pipe unless it passes through the valve, which is set at a pressure of 3 lb. per sq. in. On the Pontiac-8, it is set at 5 lb. Buick has a larger top tank capacity and the larger Ford radiator capacity raises the cooling system from 5 to 5½ gal. The Cadillac-8 and 12 continue with thermostatically-controlled shutters. The American Injector Co. is producing a simple unit with two vanes of thermostatic bimetal in one piece forming a U in cross-section approximately ¼ in. wide when warm and when cold they expand to close off the water passageway.

The Cord radiator is completely concealed under the hood. Radiator ornaments have in many cases been revamped, often incorporating an emblem within a tear-drop outline. Packard has reverted to its old bail wire as an ornament. Theft-proof construction is incorporated in many of the ornaments. Studebaker has a very deep shell which is now void of openings. The new Ford truck shell prevents air from passing between it and the core. A short distance of the Cord hood is blocked off at each side to direct the air to the radiator core. Beneath the Hupmobile grille there are invisible louvres permitting air-flow over the top of the core to decrease the under-hood temperature.

The die-cast radiator grille is very popular, forming in most instances a rounded V front and also being rounded slightly in side view. The new Oldsmobile grille has 20 per cent more opening for air-flow and is swept back further at the level of the headlamps whose stanchions project forward slightly into the grille. The Buick grille is confined to bright vertical bars which predominate in most cast grille designs, being occasionally supplemented with horizontal ones. In the Chrysler the body molding is continued forward along the hood and crosses the radiator shell and reaches around the grille. This same front horizontal grille band is used on the Chrysler Airflow. The Hudson and Terraplane have a triangular center grille portion which is wide at the top, with broad vertical bars in the Hudson and narrow bars in the Terraplane, with nine V bars crossing them in the latter. The space between the center and the radiator shell sides is filled with a honeycomb design. The DeSoto Airstream grille has horizontal bars which run into a wide center bar running up and over the radiator shell to the cowl. The sloping top border of the grille is carried back horizontally over the radiator shell and into the hood, where it is graduated in four steps and continues into the body molding.

The Cadillac radiator shell is more smoothly curved and narrower. The grille consists of horizontal bars which are slightly convex as viewed from the side and slope down and forward. The bars are ducoed in color and have a bright metal front face. A narrow chrome finish bar divides the grille centrally from top to bottom. The Ford grille has a more accentuated V and with a slightly decreased forward slope. Grilles are painted the body color in the de luxe equipped cars. The fender apron intersects the lower grille portion, producing a curved outline. The Chevrolet radiator is higher and narrower, curved slightly horizontally and vertically. Two wide grille bars and fourteen narrower bars are located on each side of the center strip.

Fuel and Exhaust Systems

The Cadillac-8s are equipped with a 1½-in. Stromberg dual down-draft carburetor which feeds a new type manifold so that no successive firing cylinders are in the same manifold. All cylinder intake ports are individual. Buick is using down draft and provides a 9/16-in. gasket to insulate the carburetor, whose jet is vented so that vapor can escape without passing through it. The Carter carburetor used on Oldsmobile, Hudson, Terraplane and others, utilizes a triple-tube venturi for better atomization. A stepped metering rod is raised or lowered with the throttle movement. An anti-percolating unit consists of a vent in the top of the float chamber, which is lifted when the throttle is closed. The accelerator pump consists of a plunger with an air bell so that discharge continues after full opening of the throttle. A dash pot is provided to prevent too rapid closing of the throttle, which might cause stalling. Chromium and cadmium plating is

used where severe wear occurs. The flexible engine mountings of today have caused wear on parts which never gave trouble with the old solid mountings.

Tillotson has developed a double venturi carburetor in which the larger venturi is provided with four reeds of Swedish spring steel which open up at high speed and tend to keep the velocity flow through the venturis constant. The Marvel B-2 carburetor is used on the Nash, Lafayette and Graham "90," the Graham "80" using the B-2SU and the Graham "110" the B-3. The air pressure in the Chevrolet float chamber is balanced with that inside the carburetor intake. The Pontiac-6 is now provided with an automatic choke and fast idle. The throttle control on the Packard "120" has been redesigned so that the first 20 per cent of accelerated pedal travel gives 8 per cent of throttle opening, as contrasted with the former 18 per cent.

A larger air cleaner is used on the Oldsmobile, having a more dense cleaning mesh. It gives 87 per cent efficiency, while the oil bath type, which is optional, gives 99 per cent. The copper mesh filtering unit of the Cadillac-8 is removable without disturbing the silencer body. Cleaning ability and dirt capacity have been improved by increased area and thickness.

The tank filler on the Cord is completely concealed by a small hinged door provided with a lock and which is part of the surface of the rear body panel. The Oldsmobile tank cap is located higher on the right rear fender to offer less resistance to fuel flow. In the Chrysler-6 and De Luxe-8 and the Airstream DeSoto and Chrysler, the filler is located atop the left rear fender and is led to the tank through a separate housing, preventing fumes entering the trunk or seeping into the body. Tank capacities have been stepped up, Chevrolet from 11 gal. to 14, Hudson 15½ to 16½, and Terraplane 11 to 16½.

The Cadillac-8s have valve ports located in a horizontal surface toward the longitudinal center of the engine from the head surface of each block. Exhaust gas is applied to the underside of the intake manifold by a passage cored in the manifold casting, which mates with exhaust port openings from the central siamesed valves of both blocks and through which the exhaust gases surge back and forth. A manifold drain prevents flooding, any surplus being carried to the ground by a tube passing to the rear along the valve alley and over the bell housing. Buick provides a manifold drain with a ball check similar to last year's Oldsmobile. The Nash "400" down-draft carburetor bolts to the cylinder head in which the intake manifold is partially cored and registers with its continuation in the block, being thus water-jacketed. In the Pontiac-6, both outer branches of the manifold have been enlarged to reduce the velocity of the mixture to the first and sixth cylinders for more uniform distribution. Dams are placed across the bottom of the two main branches to hold back any liquid fuel. Continental's ability to obtain fuel consumption figures as low as 0.47 lb. per hp-hr. is due to the use of individual intake ports combined with manifolding in which the divisions of mixture occur ahead of any horizontal bends in the manifold. This eliminates the effect of centrifugal force and distribution is independent of the type of bend used and results in practically perfect distribution, smoothness, uniform pressure drop and equal ramming effect to all cylinders.

The Packard "120" and Studebaker fuel pumps are provided with a shield placed over and downwardly in back of them to increase air circulation. Studebaker in addition provides a shield to protect the float chamber from exhaust heat, pointing it up toward the front. The combination gasoline and vacuum pump on the Cadillac-8s has been designed for quieter operation. It is now mounted on the engine front cover behind the cooling fan and is driven by a removable eccentric keyed to the front end of the camshaft.

The Oldsmobile automatic choke is built integral with the carburetor, eliminating external linkage and its adjustment, which is now set at the factory. The heat to operate the thermostat is obtained by drawing outside air by carburetor vacuum into a small chamber built into the exhaust manifold. After it is heated, it is delivered through a metal tube to the thermostat chamber, from whence it goes into the carburetor air stream. This Carter method is also found on Hudson and Terraplane. The Buick choke provides adjustment for different grades of gasoline and a large well is provided to prevent gumming of the metering pin, the assembly being sealed in a cast-iron body. The Cadillac-8s use the triple range choke mechanism introduced on the "35-50" LaSalle. When the ignition is turned on a small fully-encased wire coil located close to the control thermostat begins to heat up. This heat controls the thermostat, which in turn regulates the butterfly choke valve. After the engine reaches normal operating temperature the choke action is automatically suspended. When the choke button is flush with the instrument panel, the electric choke functions. If the button is pulled out, the choke is manually applied, while pushing it forward "dechokes" the engine.

Auburn continues with the planetary toothless driven supercharger and Graham with the cone worm gear. Supercharging is being tried out in the bus field, one manufacturer increasing the engine output by approximately 35 per cent, without sacrificing fuel economy.

There are three exhaust ports in each block of the Cadillac-8s. A cross-over pipe at the rear of the engine but forward of the last port connects the left-hand manifold with the right from which gases are conducted to the rear through two mufflers in tandem, each being a straight-through resonance type supported by rubber-insulated brackets. The Cadillac-12 has been modified by the addition of a pipe at the rear which carries the exhaust from the left-hand manifold over the top of the engine and down the right-hand side, connecting with an exhaust pipe common to both right and left-hand blocks, permitting a single exhaust system. The Nash "400" has no manifold, but the exhaust pipe is clamped against the block, fitting into three circular pads containing siamesed ports. The block surface at these points is broached to a glass-like finish, making gaskets unnecessary. The absence of the usual intake and exhaust manifolds gives exceptional access to the valve compartment. Burgess has developed an oval three-pass muffler with resonating chambers having perforated tube resonator entrances. The Cord tail pipe is chromium-tipped.

Electrical System

Vacuum-controlled spark advance has been added to the Oldsmobile and Cadillac centrifugal distributor so that during the normal driving range the spark is advanced, but retarded under wide-open throttle conditions. The Packard "120" now has Delco-Remy ignition units with octane selectors. Spark plugs of the 14 mm. type are used on the Cadillac-8s. Cadillac and Chevrolet are now using generators with the ventilating fan blades on the back of the drive pulley. The Cadillac and LaSalle regulators are mounted on the forward side of the

dash. Double reduction starter gears are omitted on the Cadillac-8s and the starter is mounted on the right side of the engine in front of the bell housing. With more flexible engine mounting it is desirable to isolate the driving controls from the powerplant to prevent transmission of noise and vibration to the front compartment. The Oldsmobile starter control consists of a dash-mounted plunger which when depressed contacts and actuates the control arm on the positive shift starter. When not in use, there is no contact with the arm.

Engine Mounting

Soft front mountings are used by Oldsmobile to permit slight radial movement for the absorption of torque reaction. Closer control of fore and aft engine movement is obtained by incorporating an outer steel cup around the inner with a relatively thin layer of rubber between them. The rear mountings are located at the rear of the clutch housing. This allows approximately 6 in. less spread between them, decreasing the rigidity to torque reaction. In the Cadillac-8s, the four point supports are supplemented by engine stay rods. The Studebaker rear mountings are set at a 45 deg. angle, just back of the clutch housing. There is a single mounting at the front and on the over-drive models at the rear end of the transmission. Firestone is making mounting biscuits in which fabric is incorporated to restrict horizontal movement. On the Nash "400" a wire spring is incorporated in the biscuit to give a combination rubber and metallic resilience.

Clutch

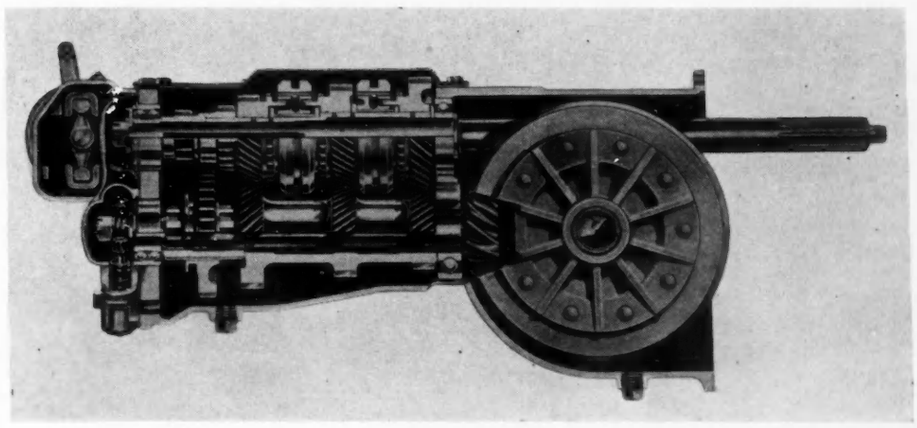
Soft pedal pressure and improved cushioning still prevail as the desirable clutch characteristics. In the latest Borg and Beck clutches the single crimped disc has been replaced by a flat disc on which are a number of clock steel cushion springs. The disc, divided into nine segments, is heat-treated and drawn and held to close flatness limits to insure freedom from runout. The plate cushion springs are warped in one plane, having crowns of two different heights. The facing on the flywheel side is riveted directly to the flat steel disc and the same rivets pass through holes near one end of the cushion spring. The other end is restrained against radial movement from centrifugal force by a tongue engaging a T-slot in the disc. The facings on the pressure-plate side are fastened by short rivets directly to the center of the high crown of the cushion spring. There are three distinct stages of cushioning action, the first being due to the high crown position as regulated by the tongue bottoming in the T-slot; secondly, when the base of the high crown seats on the disc, and thirdly, when the low crown is brought into action. The initial cushioning is extremely soft and has been found to be particularly effective in wiping out drive line rattle when the torque is barely enough to move the car on level road. The design of the cushion springs can be easily varied to suit the characteristics of different installations. The Borg and Beck driven assembly is used on the Buick "40," the cover assembly being made by Buick.

The Long semi-centrifugal clutch has been slightly modified to facilitate production and is being continued by Ford, Packard "120," LaSalle, and has been adopted by Cadillac in the 11 in. size for the 8s and 12, the former having coil spring vibration dampers in the hub, while the latter requires none.

Auburn is using the 10 in. size on the 8-cylinder, 228 ft-lb. torque engine. The Long driven assembly is used by Pontiac and the large Buick engine, the manufacturers providing their own cover assembly. The Chevrolet clutch disc cushioning springs are given considerably greater life by means of a "shot-blasting" treatment consisting of exposing the wire to the blast of lead pellets which peen the surface evenly and cold-work the metal to such an extent that its fatigue strength and endurance capacity under repeated stress are multiplied nearly twenty times. Buick is using woven clutch facings with larger areas. The "40" is 9½ in. in diameter and the facings for the large engine are 11 in. Cadillac likewise uses woven linings. The Buick clutch throw-out mechanism is of the horizontal lever type introduced by Oldsmobile. The clutch discs of the latter are balanced by the addition of small metal clips when necessary. The Aetna "T" type clutch release bearing is made with a ball retainer of impregnated bronze and with the original lubricant sealed in. The retainer keeps both races in alignment, eliminating eccentric throw. The Eaton clutch actuator is now carried on the transmission, instead of the clutch cover. As before, actuation is brought about by frictional contact causing partial rotation of an axial cam. A brake actuator is being developed along these same lines. The Hudson and Terraplane vacuum clutch cylinder has been increased in length, increasing the travel of the clutch mechanism, giving better timing for quiet and easy shifts.

Transmission

The transmission for the large Buick engine has been entirely redesigned, is more compact and weighs 36 lb. less than its predecessor. The second-speed mainshaft gear is



Cord Four Speed Transmission

mounted on needle bearings. The actuation of the synchronizing cones involves the use of three dumbbell rollers guided at their ends in the rod-spaced cone cages and actuated by the positive clutch member through the intermediary of detent springs encompassing the ends of the clutch member and entering at their hump center the central notch of the rollers. The Cadillac "60" transmission is a new design and provided with inertia type synchronizers. The larger 8s and 12 are of the old design with hydraulic synchronizers. Pontiac and Ford have adopted the helical first-and-reverse sliding gear on a helical spline. Hudson and Terraplane have wider-faced gears except for second and a new tooth chamfer for easier engagement. The Warner overdrive is optional equipment on all Nash products, Studebaker Dictator and Hupmobile. Available at extra cost on the Chrysler-6 and De Luxe-8, the overdrive unit is incorporated in the same case as the transmission, making a considerable reduction in overall length and simplifying the reverse lockout by the sliding transmission gear contacting directly with the overdrive locking sleeve.

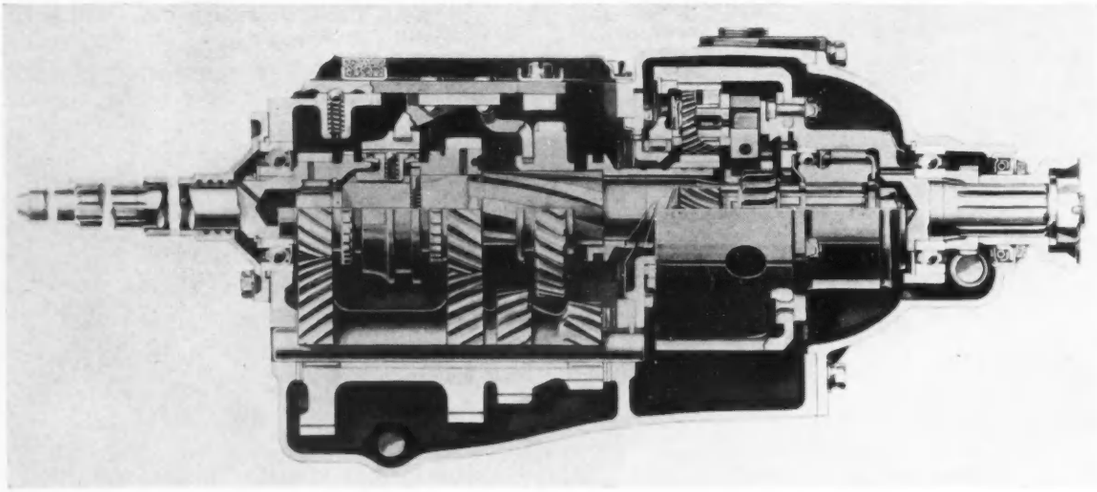
The differential and transmission housing comprise a single unit in the Cord with a common case and the differential between the clutch and the transmission. It is of the indirect drive type with a mainshaft 3 15/32 in. above the countershaft and differential. First and reverse is accomplished by a sliding gear on the countershaft. Second, third and fourth are obtained by constant mesh 45 deg. helical gears with synchronizers and clutches on the mainshaft. The highest ratio is a cruising speed with an overall reduction between engine and wheels of 2.75 to 1. Low is 9 to 1 and third 3.88 to 1. In order to place the maximum weight and the body dash forward, the transmission is located ahead of the differential and furthermore the differential center is 1½ in. ahead of the normal wheel center.

A spring has been added on the Packard "120" control to urge the shift lever over to the right side and its leverage has been changed to shorten the shift. Ford has raised the lever fulcrum to reduce its travel ⅜ in. and the lever has been moved forward for more leg room in the front compartment. Chevrolet is now using a rail-type shifting mechanism with an interlock to replace the former plate type. The Hudson and Terraplane electric hand is of improved appearance, having a circular end cap incorporating the quadrant. A similar Bendix control under the wheel is used on the Cord with fourth speed in a slot to the right and forward. It does not emerge from the neutral slot, but starts back of same between neutral and third. The shifting rod selector shaft is located at the front of the transmission case and is actuated by a diaphragm unit at the right, to which vacuum can be led on either side. A spring on each side of the diaphragm centralizes it where it engages the second-third speed shift rod. Vacuum admitted to the right side of the diaphragm moves the selector shaft to the right to engage the fourth-speed shift rod, whereas vacuum on the left side causes engagement of the first-and-reverse. A vertical lever on the selector shaft is connected with the piston rod of the shift cylinder, whose piston is actuated by a vacuum admitted to either side. The shift cylinder is supported at its back end by a rubber mounting to take care of angularity due to movement of the selector shaft as well as vertical movement when its lever connection travels in an arc. An interlock switch is actuated by the selector rod and a neutral switch is incorporated in the front end of the shift cylinder to bring the piston to the center of its stroke (neutral position) when the operator selects neutral or whenever a cross shift is to be made.

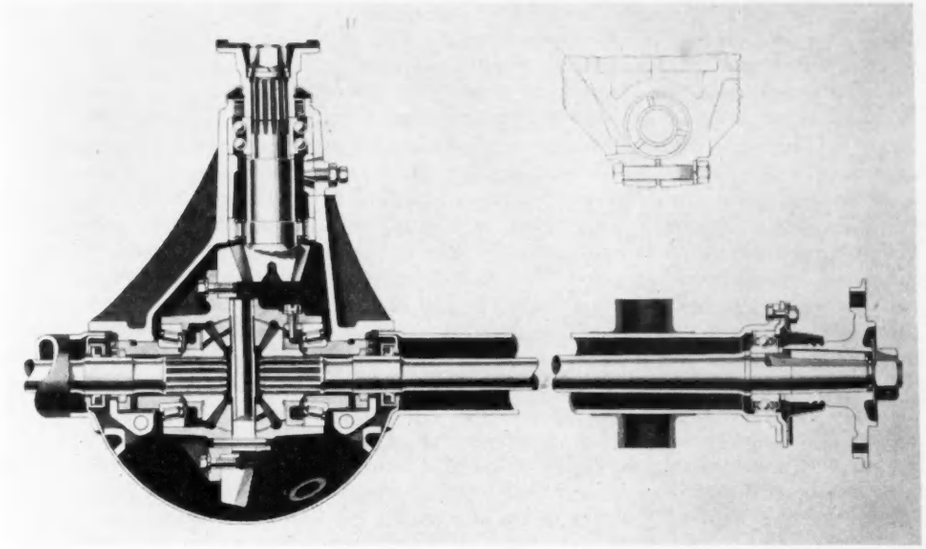
Propeller Shaft and Rear Axle

The Cadillac propeller shafts are of the same lengths on the 8s and 12, the difference in wheelbase being taken care of by the length of the transmission extension. The Ford truck is now equipped with needle bearings in the universals. The front drive shafts of the Cord utilize the Rzeppa constant velocity joints. The 4200 series joints of the Universal Products Co. are used on Plymouth and Dodge; the cross-type with conventional flanges on De Soto, Chrysler, Hupmobile, Packard and Pierce-Arrow. A cross-type in which one yoke is provided with a take-down mounting for the needle bearing cups is used on Dodge trucks.

Increased engine output permits faster axle ratios. The Packard "120" has been changed from 4.36 to 4.09 and the engine revolves 315 fewer revolutions per mile. Packard continues with the hypoid gear, as does the Chrysler-6 and De Luxe-8 and the De Soto Airflow. Cadillac holds its gears to a limit of 3/10,000 in. and they are carefully matched to eliminate back lash and to provide silent operation. The new Plymouth rear axle has larger wheel bearings and thrust is now distributed to the bearings through a hardened thrust block. The torque tube, propeller shaft and rear axle are the same on the Buick "60" and "80" except for differences in



Chrysler Automatic Overdrive and Transmission Unit



Cadillac Semi-Floating Axle with New Differential and Sealed Wheel Bearings

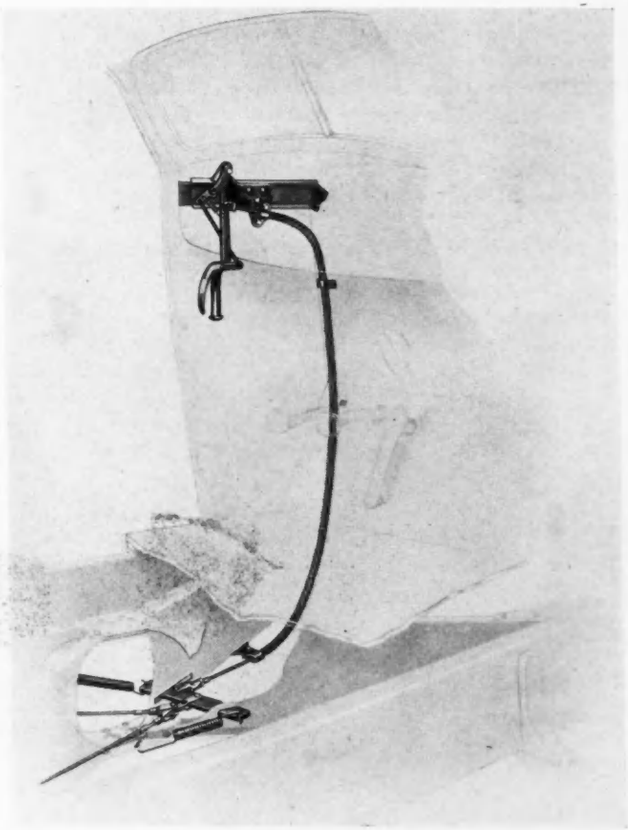
length and final ratio. A two-pinion differential is used on all the Buick series. In the Cadillac 8s and 12 and LaSalle a cylindrical-shaped differential is used having a heavily ribbed solid case and the supports are tapered roller bearings with stationary inner races. The differential is of the two-pinion type and gears are assembled through one end and retained by a threaded ring. Permanently sealed wheel bearings and semi-floating construction are used and the cover is welded on for added strength. Buick is following Oldsmobile in the use of molded rubber pads to insulate the rear axle from the springs and frame at the spring seats. The Cord rear axle consists of a steel tube flange on each end to take the wheel spindle forging, which is offset ⅜ in. above the tube axis.

The Chevrolet truck is equipped with a full floating axle and the wheel bearings are special Hyatts with self-aligning rollers with their axes in conical formation. The bearing surface of the rollers is ground radially and races ground to a slightly larger radius permit greater contact area with increasing load and elastic deformation. The axle tubes are pressed a distance of 5⅞ in. into the malleable iron center housing under 12 tons pressure and riveted in place. A hardened bronze bushing 1 in. long is pressed into the extreme forward end of the torque tube serving as a bearing for the universal joint rear yoke. The Ford truck shafts have been increased to 1 9/16 in. diameter and hardened steel yoke stud adapters are used to prevent the flange from developing any play on the studs. A new design of two-speed axle has been developed by Eaton for trucks up to 20,000 lb. gross, similar to the previous 12,500 lb. model. Ratios are 6.43 in the high range and 8.74 in the low. A planetary sun gear is shifted to and held in a stationary position for the 1.36 reduction or moved and locked to the planet gear carrier.

The Timken "mirror finish" on the bearing races is the result of cooperative work by the Timken organization and various abrasive manufacturers and machine tool builders to develop the right coolant, the proper grits and the correct wheel speeds and feeds.

Brakes

With the adoption of hydraulic brakes on all General Motors units, the mechanical brake occupies a very limited field and what its advocates will do in the future will be interesting to note. Cadillac is using the duo-servo brake with larger front-wheel cylinders, so that 56 per cent of the braking effort is placed on the front wheels for the "60" and 58 per cent on the other series. LaSalle runs 55 per cent on the front. In the Chevrolet system a 1 in. diameter master piston is used in conjunction with a 1¼ in. piston for the front wheels and a 1 3/16 in. at the rear, placing 52½ per cent of the braking effort on the front wheels. The wheel



Oldsmobile Hand Brake System

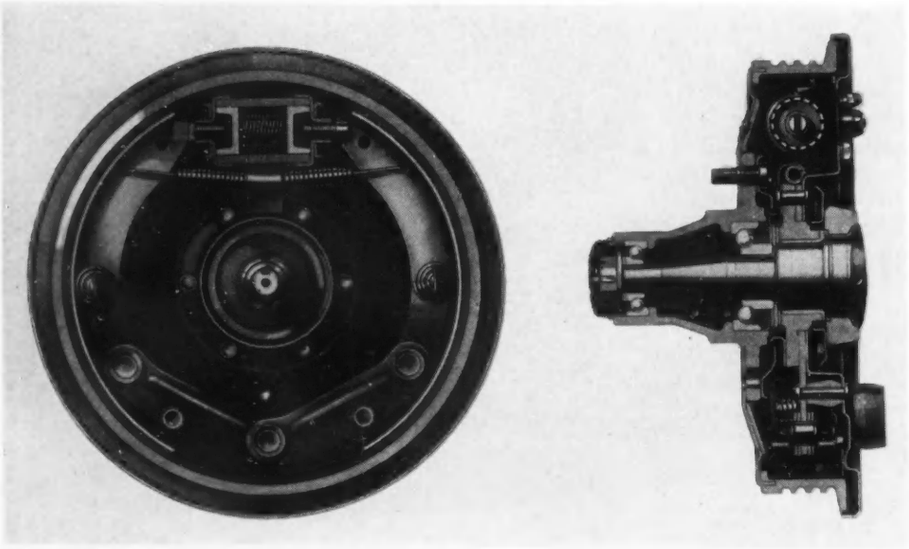
cylinder construction is of considerable interest. Aluminum pistons press against an end cap which pilots over the machined outside ends of the cast-iron cylinder and into the center of the cap extends an adjustment screw whose slotted end encompasses the shoe web, preventing the screw from turning. An adjusting wheel with deep teeth formed in its flanged periphery is welded to the end cap and the unit is rotated by inserting a screw driver through an opening in the backing plate. The end cap is locked by a spring steel lever engaging flutes on its outside diameter. The heel end of the shoes are anchored by links. The clearance hole in the links over the anchor pins in the heel end of the secondary shoe is similar to the articulation method introduced in the previous model to prevent excessive toe wear. To preserve interchangeability the primary shoe is made likewise but the pin and holes serve no purpose. In the Oldsmobile, Buick and Chevrolet tubing is used in which sheet steel is rolled to form a tube with two layers of metal which are permanently bonded together by a hydrogen welding process. This tubing has a bursting strength of over 10,000 lb. per sq. in. At the connectors the ends of the pipes are flared at an angle of 45 deg., with the lip of the flare bent inward to form a double thickness. A union nut of copper-plated steel, slipped over the tube before it is flared, threads into the connector to lock the tube in place. The connector is made from close-grained wrought brass.

In all the Chrysler units the brake cylinder pistons are made of duralumin instead of aluminum and bronze replaces aluminum in the master cylinder piston to prevent the possibility of corrosion. The Studebaker "hill holder" to prevent backing when stopped on a grade consists of a check in the fluid line just ahead of the master cylinder. The pressure is retained as long as the clutch is held out. In this way the driver can remove his foot from the brake and use it on the accelerator as the clutch is let in. The Nash "400" uses the Bendix single anchor "equal action" type mechanism actuated by a single hydraulic cylinder mounted on the backing plate. In the Bendix "twinplex" brake there are two shoes in each drum, each with its own anchor and applying mechanism, mechanical or hydraulic. Shoes are self-energizing in both directions.

Hudson and Terraplane provide "duo-automatic hydraulic braking" in which a complete hydraulic system is backed up by a mechanical interconnection with the hand brake cable hook-up to the rear wheels. The mechanical brake comes into play after three-fourths of the pedal stroke by means of a link connected with the rotary equalizer of the mechanical brake system. In normal braking with the foot, the mechanical brake is inoperative. Buick is using woven linings, whereas Cadillac utilizes them on the secondary shoe and molded on the primary. Pontiac is equipped with molded linings. General Plastics has introduced two improved thermo-setting phenolic resins for use in rubber and impregnated woven-type linings which provide greater resistance to oil, water and heat and a more uniform coefficient of friction.

Centrifuse brake drums are used on the Cadillac 8s and 12 and the Buick "40." A cast-iron drum is found on the other Buicks. The Chevrolet Master uses a composite construction comprising a cast-iron rim which is cast with and fused to a pressed-steel backing plate. The outer drum surface is provided with five cooling ribs. The internal diameter has been reduced from 12 in. to 11 in. The Chevrolet Standard retains the pressed-steel construction, but the drum is 1 in. larger in diameter, increasing the braking area to 158¼ sq. in., making like shoe assemblies in both the Master and Standard. In each case the drums are now mounted on the outside of the hub flange. One-piece solid T-section shoes replace the former two-piece, which had the face and web welded together. One-piece dirt shields are used.

A dash-mounted inverted hand brake lever at the left side is used on the Cord and Oldsmobile. In the latter a flexible cable is sheathed in a metal conduit and connects to a floating lever pivoted at one end in a short slot in the right front section of the frame x-member while the opposite end slides in a guide slot in the left member. Steel cables run in practically a straight line to each rear wheel brake and attach to the lever at a common point a short distance from the hand lever cable toward the fulcrum side. Loading on the cables and two coil springs hold the lever in position. The cable of the Buick dash-mounted lever actuates a short cross shaft at the x-member with a lever at each side for the rear brake cables. The Packard "120" lever is more accessibly located, its leverage has been increased and an equalizer replaces the



Chevrolet Hydraulic Brake

former cross shaft. The Chevrolet hand brake lever is supported on the frame at the driver's right and actuates the rear brake shoes by cable. A heavy spring between the lever and the pull rod permits the pawl to engage the next tooth of the ratchet after the brakes make full contact, maintaining constant tension to compensate for contraction or expansion of the drum and shoes. The Plymouth, Dodge and Chrysler-6 and 8 hand lever is now mounted on the frame, so that it will not shake during car operation.

Front Axle

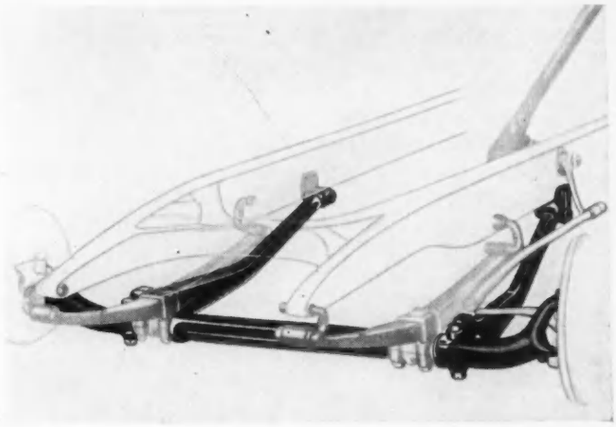
Terraplane and Hudson C-shackle the front springs at both ends, the spring seats swiveling on the front axle. A radius rod is used on each side to take the brake torque and is attached by a large vertical pin to the axle bed and is anchored below the side rail by a rubber-bushed pivot bearing. The front springs take side thrust and are more flexible, the unit deflection being 110 lb. per in. as compared to last year's 235. Front axle caster on the Ford truck has been increased to 4¾ deg. from 3½ deg. and the camber reduced to ¾ deg. from 2 deg.

Wheels and Tires

The wire wheel is practically extinct, being used only on a few export models. The Ford spoke type pressed-steel wheel with the rim electrically welded at each of the 15 spokes is 5 lb. lighter than the previous wheel and is formed from 0.110 in. stock and a 12½ in. hub cap with a polished stainless steel center is used. The Chevrolet Standard is also equipped with pressed-steel wheels in the place of wire. The Packard "120," by increasing the thickness of the stock 0.020 in., has reduced tire noise. The larger Packards are using wire wheels with a steel cover in most cases. The single disc prevails and Motor Wheel design comprises the holed type for Plymouth, De Soto, Chrysler-6, Hudson, Graham and Reo. The spoke type is used on Buick and special equipment on one of the Packards. The plain conical disc type is used on the Cadillac, LaSalle, Packard "120" and Auburn with a full cover. Motor Wheel holds the run out and rim wabble to within 1/16 in. total indicator reading. The Buick "60" and Packard "120" wheels are held to a maximum out-of-balance of 15 in.-oz. and Cadillac, 7. Accessory disc covers are available on the latter, being a concentrically ribbed design in color or chromium plate. Balancing lugs are fitted to the front-wheel rims of the Pontiac-8 and De Luxe-6 to keep the balance within 10 in.-oz. Cord has a deeply-dished disc wheel with twelve 1½ in. holes adjacent to the periphery of the 11 in. Centrifuse brake drums. There are corresponding holes in the chromium-plated wheel cover to assist cooling. Buick has optional chromium-plated trim rings.

Practically the entire 1936 production will be on 16 in. dropped-center rims. The exceptions are the large Packards, Pierce-Arrows, Lincolns and the Cadillac-16, which continue on 17 in. The Buick "60" has 7.00-15 tires, being the first original equipment move to lower than 16 in. This may presage a further adoption of the 15 in. in the future, since the wheel and tire proportions are very pleasing. However, brake clearance may prevent it, together with the question of tire mileage. Smaller diameter tires wear faster proportionately than the decrease in circumference.

The elimination of tire noises has again been improved by getting away from the all non-skid designs. Tire durability averages are going down since the increased car performance and particularly better riding comfort produces higher speeds and the resulting wear is proportionately greater than the improvements that the tire manufacturers have been able to make from year to year on tread wear durability.



Front Axle Radius Rods on Hudson and Terraplane

Radio interference due to static produced by tires and producing a spark jumping through the grease in the front wheel bearings has been reduced materially by certain tread compounds in some experimental work by Firestone. Its existence has been proved by applying the brakes to ground the wheels to the car body through the brake lining wire and also inserting "static collectors" in the front-wheel caps to ground the wheel to the end of the spindle. One terminal of an electrostatic voltmeter was connected to the car and the other terminal grounded by means of a dragging chain. On a concrete road the needle went off the dial after running 100 ft., indicating that more than 3500 volts were being generated. At 40 m.p.h. steady sparking occurred over a 0.070 in. gap (0.075 in. occasional) with an adjustable spark gap connected between the car and the earth. Passing under high tension lines also gives the car a static charge.

The Goodyear Lifeguard tube is standard equipment on the Chrysler Airflow and optional on the remaining Chrysler products as well as Nash, Hudson and Packard and is a most worthy development in the interests of safety. Firestone is in production on the Ground Grip tire for use where traction is poor and chains otherwise necessary. Firestone and Goodyear have been active in the production of tires for large dirt hauling units, using pressures ranging from 30 to 40 lb., with a fewer number of plies and a large cross-section to provide "flotation." The 18.00-24 tire weighs approximately 500 lb. and has a carrying capacity of 15,000 lb. The Stop-Start Goodyear tire has a special but heavier tread. The shoulders have deep notches to dissipate heat and the skid portion of the tread is up to 30 per cent deeper than standard size.

Suspension

To obtain a 50-50 weight distribution, the engine of the Buick "60" and "90" has been moved ahead 6 3/16 in., the Studebaker Dictator 4⅛ in. and the Lafayette approximately 6 in. The side sway eliminator of the Plymouth, Dodge, Chrysler Airflow and De Soto Airflow remains at the front end of the chassis, but is mounted on the frame. In the case of Plymouth and Dodge the cross bar extends transversely ahead of the shock absorbers, being attached to their arms. The Chrysler-6 and De Luxe-8 have a similar bar mounting on the shock absorbers, but at the rear. Buick and Cadillac have

front-end stabilizers with a rear one in addition on the Cadillac. On both these cars the engine sump is shaped to clear the bar, which is bracketed to the frame side rails. Operating levers formed on the shaft extend forwardly and are linked to the spring trays of the lower suspension arm.

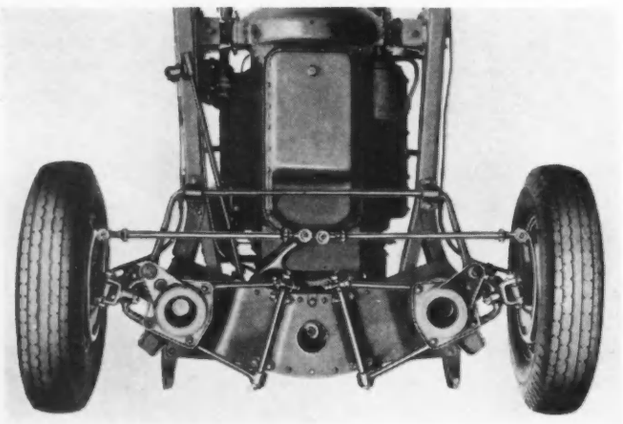
The Buick rear springs are eccentrated 4½ in. Except on the "60," the Cadillac rear springs are mounted outside of the frame. Tapered ends are incorporated in the Packard "120" springs. Both Plymouth and Chevrolet Standard have front-end rubber bushings. The Cord rear spring is an eight-leaf, 54½ in. long x 2 in. wide semi-elliptic with a deflection rate of 120 lb. per in. Rubber bushings are used on all spring bolts, including the rear located shackle. Two main leaves are incorporated in the Hudson and Terraplane front springs. The Chevrolet Standard front spring has been increased from 33 in. to 36 in. and the deflection rate dropped from 315 lb. per in. to 209. The rear springs have been shortened from 54 in. to 49 in. and the deflection rate increased from 105 to 112. These changes were made better to equalize the relative frequencies. The Nash "400" deflections are 125 lb. per in. for the front and 120 for the rear springs.

The Cadillac rear spring front bushings are rubber on all models. The lower shackle bolts are threaded and the upper ones plain and rubber-bushed, except on the "60," where both upper and lower bolts are threaded. The Chevrolet Standard front spring shackles are now located at the rear end of the spring. Threaded bolts are used throughout, front and rear, except the Inlox bushing at the front of the rear spring. The shackle side links fit over the tapered ends of the bolts, with a center holding bolt similar to the former Tryon shackles, but with a smaller angle to the taper to prevent rotation. The Plymouth and Dodge shackle is located at the front for fore and aft steering in place of the previous cross steer. A spring type kick shackle is located at the rear of the left front spring.

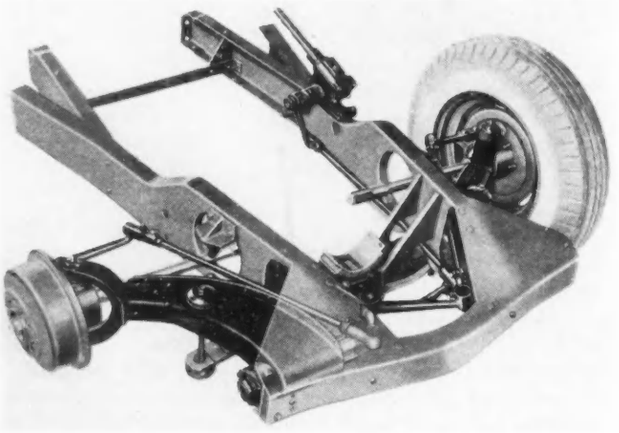
The torsion bar method of suspension has been used in an experimental way by the Truck Equipment Co. A silico manganese steel bar placed alongside the frame rail has lever connections to conventional axles.

Individual Suspension

The Chevrolet spindle is now pressed into the support arm under 10,000 lb. pressure and the inner end peened over. Zero toe-in and camber are provided in the Pontiac-8 and



Cadillac "60" Front Sway Eliminator, Suspension and Steering



Cord Front Suspension and Center Steering

De Luxe-6. The lower suspension link arm on Buick and Cadillac is pivoted on a shaft and in both lines the frame side rails pass through the front cross-member except in the case of the Cadillac "60," where the rail is still formed outwardly to enclose the coil spring. Otherwise the front cross-member houses the springs at each outer extension. With the rubber bumpers located outside of the springs, the trays are left open, permitting any dirt or ice that may collect to drop out. The Oldsmobile frame rail still encompasses the coil spring. Severe stresses on its top link arms will bend them without damage to the shock-absorber body, yet they are of comparable strength to the previous arms. The shock-absorber mounting bosses have been made stronger so they can more adequately withstand severe shocks. Reduced unsprung weight and greater road clearance in the Oldsmobile and Buick are secured by the use of a lower arm consisting of two separate parts which are united by the spring trays and by the elimination of the upper and lower control arm yokes. Bolts are used in the Oldsmobile trays, while Buick rivets them.

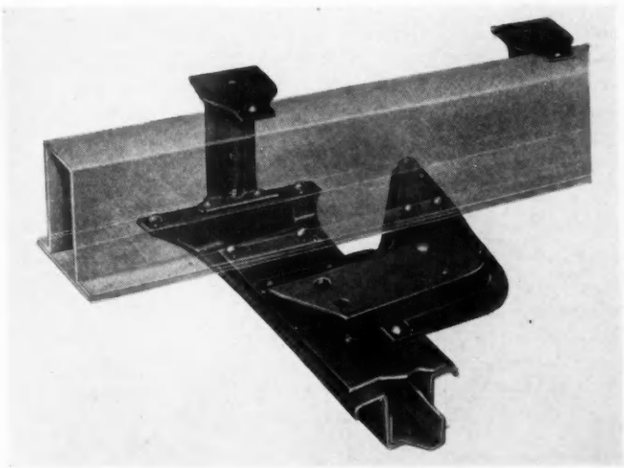
The Packard "120" front-spring rates have been reduced from 90 lb. per in. to 75 and the rubber bearings at the upper end of the vertical wheel support and at the rear of the radius rods have been softened. The Studebaker Planar suspension, standard on the President, has fifteen leaves and the rate is reduced from 250 to 225, while on the optional Dictator thirteen leaf spring the rate is cut from 225 to 210. The Cadillac "60" has a T-shaped center steering lever and an L lever is used on the other series, which is also retained on Buick. Needle bearings are used in the Cadillac king-pin bearings (except the "60") while camber and toe-in have been reduced.

Cord uses individual front suspension with center steering. The second cross-member which supports the powerplant in a rubber ring mounting above it receives the center of a single transverse front spring. The front cross-member is offset slightly to the rear to support a horizontal tube at each side about which the front wheel arms oscillate on widely-spaced Timken bearings. The wheel arm consists of a curved U-shaped stamping of ⅛ in. stock with a vertical plate riveted and welded to complete the box section. Tension shackle rods pass through clearance holes in the arms and spring ends and transmit the load by means of rubber biscuit mountings on each end. A forged knuckle is riveted to the back end of each arm. A frame-mounted tapered rubber bumper limits

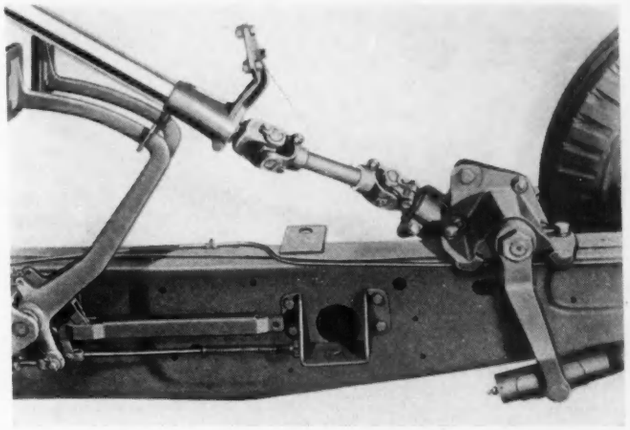
the arm travel. The cross spring has 14 leaves, 34 in. x 2½ in. and 950 lb. per in. deflection, which is equivalent to 150 lb. at the wheel. The oscillation period is around 70. A jack is easily placed under the wheel arms. Front wheels are piloted on New Departure preloaded, angular contact bearings with a 2 in. spread between contact points.

Frame

Increased rigidity has been the aim of the designer and this has been accomplished by deeper frame rails and particularly by a more rugged x-member construction. Frame rail reinforcements have also been modified to this end. The Oldsmobile frames are made sufficiently rigid to take care of convertible bodies. Exceptionally thick steel plates are inserted between upper and lower x-member flanges. A 25 per cent increase in overall rigidity is claimed. Buick, likewise, uses large plates at the intersection of the x. The Cadillac x-members extend all the way to the center and are welded together at this point, only the upper portion of the webs being cut away to permit passage of the propeller shaft. At the four junction points with the frame rail, the x-member and the rail reinforcements are welded into one unit. The "70" as compared to the previous series "10" frame shows a torsional rigidity increase of 275 per cent, while the forward portion as measured from the body dash to the center line of the front wheels is 240 per cent greater. All members of the Reo frames are welded. All the Chrysler products other than the Airflows have a one-piece barrel-shaped section at the x-member center with continuous channels on each side. In spite of a decrease of 68 lb. on the "60" frame and 33 lb. on the "90," the increase in torsional strength on the Buicks is 114 per cent and 144 per cent respectively. These frames are 90 and 44 lb. heavier when used with convertible bodies. Cadillac frame rails are now straight and those of the Chrysler products conform to the body sill outline. The Chevrolet Standard frame rail consists of an inverted U section with out-turned flanges to which a flat closure plate is welded every 1⅜ in. The front and ends are closed by brackets. A reinforcement is riveted within the box section at each shock-absorber mounting in the form of a steel sheet with rolled ends through which pass the shock-absorber bolts. The Cord powerplant, transmission, front suspension and steering gear are mounted in a separate frame which is attached to the body frame, the latter forming an integral base for the body. The channels of each frame telescope each other and are bolted together where they overlap. In addition two diagonal braces connect the powerplant frame with the body frame cross channel. Electric welding is used throughout each frame.



Chevrolet Box Type Frame Rail with Second Cross Member and Pedal Support



Cadillac Steering Column with Universal Joints

Control

Two metallic universal joints are interposed between the frame-supported steering gear and the body-supported steering column on the Cadillac 8s (except the "60"). Steering is thus immune from relative weave between body and frame, and vibration and wheel whip are reduced. The appearance of the wheel has been improved by the elimination of the throttle and light controls and changing the spoke shape to a streamline section. The horn button is of a natural wood. Flexible spoke wheels of the rod type are optional on Cadillac, Hudson De Luxe-8 and the Buicks with the exception of the "90" where it is standard. The Cord wheel has spokes of flat spring steel and the horn is operated by a ring actuated by the thumb. A center Y lever supported by the second cross-member is controlled by the steering gear. A ball at each end of the Y lies on the pivot axis of the suspension arms and is connected by a drag link passing diagonally backward through an opening in the frame rail to the spindle arm. The Chrysler Airflow steering gear with an upturned lever is mounted behind the front axle resulting in the rim of the wheel being completely out of the line of vision. A drag link runs forward to a vertical two-armed lever whose center and lower arm drag link connection to the wheel spindle simulates last year's geometry. The Chrysler-6 and De Luxe-8 have cross steer with the individual wheel suspension. The Plymouth reduction ratio is 18.2 to 1 and Ford has dropped from 15 to 17 to 1 which with lengthened spindle arm gives a 13 per cent increase in leverage. Needle bearings are used in each end of the steering arm sector shaft and the worm and sector teeth are ground and lapped. The adjustable drag link permits the high spot in the gears to be set in the straight ahead position. The Oldsmobile wheel is finished with a clear lacquer to prevent the rubber from rubbing off, especially during the hot weather. The Cord wheel is of tenite to match the exterior of the car.

Equipment

Cadillac horns are mounted between the radiator brace rods and supported in rubber bushings to avoid transmission of vibration to the body. An air trumpet horn replaces the vibrator type on the Buick "40."

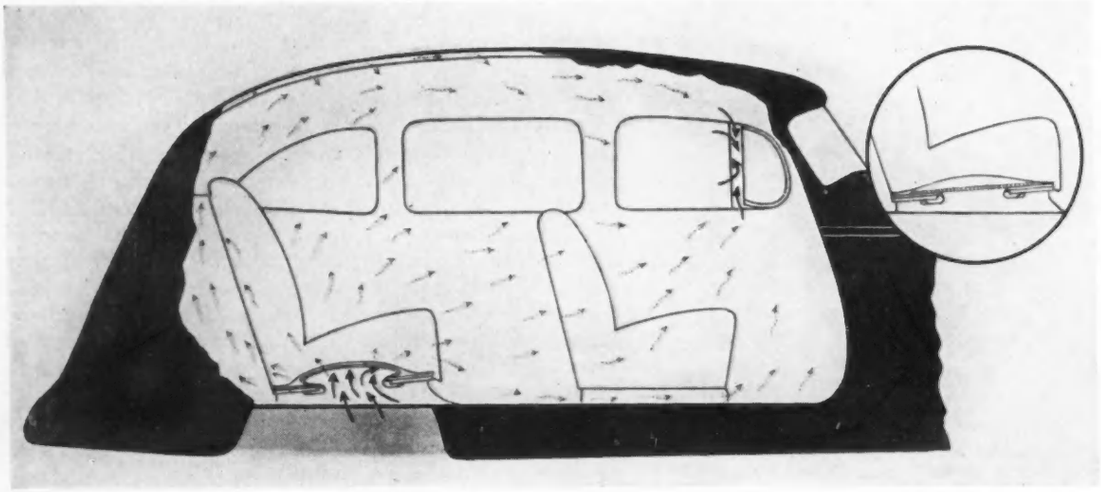
Headlights are generally smaller in diameter and are mounted on the radiator sides in Buick, Cadillac, Chevrolet, Pontiac, Reo, Dodge, Chrysler and DeSoto. The Oldsmobile lamps are mounted higher and placed closer together. Instead of the conventional V filaments, the General Electric Mazda lamp No. 2331 has two horizontal coiled "bar" filaments located side by side but with the passing filament slightly above the other. The lower right-hand filament (viewed from driver's seat) is used in each headlamp to provide the driving beam of symmetrical pattern. The upper left-hand passing filament provides an asymetrical passing beam. It is shifted down and to the right about 3 deg. An opaque coating on the end of the bulb masks the direct rays which normally do not strike the reflector. Scattered light is reduced thereby improving visibility through a haze or fog. Tung-Sol has a similar fused-on cap but it is translucent. This type lamp is used on Plymouth, Dodge, DeSoto, Chrysler, Studebaker, Nash, Hudson and Terraplane. The Oldsmobile lamps are mounted solidly with the radiator shell and aiming adjustments are provided to tilt the reflector. This same Guide feature is used by Pierce-Arrow. The Cord headlamps are retractable into the fenders where they are completely concealed. They are rocked into position by turning a crank on the instrument board which actuates a worm on each lamp through a flexible shaft.

The Oldsmobile tail lamps are mounted lower on the rear fenders and nearer the center of the car. Pontiac has shifted them to the fenders while Terraplane mounts them on the luggage compartment lid. The Cord tail light is set flush in the lower part of the lid and the license bracket is bolted directly in the center of and close to it.

Instrument panels are characterized by the increasing use of color both in mass and line. This has been accomplished by the use of large areas of cream, various metallic browns and tans, blue grays, etc., enlivened by stripings and spots of red. There is a continued tendency towards condensing the instruments into as few groups as can be conveniently arranged on the instrument board. Further steps have been made in improving the lighting of instrument panels so as to get more even distribution of light, less glare and stray light. Buick's panel with "edge lighting," an A. C. development, gives at night a very soft light yet the figures and graduations are plainly visible. In the case of the Buick panel, a light cream background changes to a deep black against which the figures and graduations stand out. They are printed on the back of the glass and the light is directed to its edge. The figures seem to glow with a soft self-induced light. By cupping the dials as on the Chevrolet, and the figure rings as on the Oldsmobile, a very uniform and pleasing appearance at night is obtained. The pointers on the various panels range from polished aluminum to give an appearance of richness to white or brilliant red, or combinations of red, black or cream which cause the pointers to add a touch of warmth. An interesting point in the development of "edge lighting" is that the rough cut edge of the glass is found to be a better surface for producing uniform lighting than a polished edge and very much better than a ground edge.

Pilot lights have been added to indicate the use of the upper headlight beam and in the case of Cadillac and LaSalle all four beam positions are indicated. In these cars the entire instrument panel is a single die casting. The Chrysler Airflow has a combined speedometer and tachometer. The indicator points to three sets of figures showing miles per hour, engine speed in high gear and engine speed in overdrive. A number of cars have the oil level gage with button control. Many of the Cord controls are operated by levers which work up and down similar to airplane controls.

The large Packards retain ride control of the shock absorbers. Cadillac has eliminated it on all models except the "90." The Fleetwood Cadillacs have 1¾ in. double-acting units with end-to-end discharge. The front shock-absorbers have been simplified by the use of two control valves instead of three, the orifices being combined with the relief valves. The rear units have inertia control and are also equipped with a "clicker" control permitting manual adjustment. The "60" shocks are 1½ in. double-acting with center discharge. The Cord units are all of the inertia type. Plymouth and Dodge are double-acting on the front springs. The Gabriel-Wolex design provides for hydraulic action between a movable cylinder and stationary piston which are combined in a self-contained cartridge fitted into the shock-absorber housing. The Monroe direct-acting shock-absorber on Terraplane and Reo utilizes a circular disc spring retained valve in place of the previous ball check type.



Hudson and Terraplane Dustless and Draftless Ventilating System

The Oldsmobile provides a heater water-circuit from a tapped hole at the center of the cylinder head to the heater and a return to the pump inlet. Hudson provides a plug at the back of the block and also one on the line from the radiator to the pump inlet for the same purpose. The Hudson and Terraplane radio antenna is stone and waterproofed and is mounted beneath the car between the running boards. The Lincoln Kleenseal lubricating fittings used on Pontiac, Buick, LaSalle, Cadillac and Hupmobile, are provided with a circumferential groove below the spherical head giving an anchorage for the inturned flange of the gun when it is tipped at a slight angle. The plunger is vacuum primed or with heavy greases a follow-up screw is used.

Sheet Metal

A greater number of cars are extending the front fenders down to the bumper level and are using the creased crown. Stainless steel trim strips are used on the fender apron, together with chevrons on the crown front. The DeSoto horn housings on the apron have a pronounced taper and a replica of the radiator grille. Ford provides round grilles with vertical bars in front of the horns. The Nash "400" front fender is made rigid with the body and fastened to the frame only at the forward tip. The radiator is mounted between the fenders on a cross rod attached to them and is entirely free from the frame. A system of "A" bracing links the fender and radiator assembly with the body cowl to which is hinged the hood and grille. The rear half of the Pontiac rear fender is raked further back to a point below the wheel center. The Cord rear fender has a chromium-plated tip of considerable height at the front.

Pontiac, Oldsmobile, Buick, Nash, Hupmobile, Hudson and Terraplane have extended the top section of the hood so as to be flush with the rim of the radiator grille which gives a sweep that is not obtainable with the use of a radiator shell. The Ford hood top is longer and extends forward with a curled under-edge to the top of the grille. Most louvres use horizontal line design which, however, is broken up in the case of LaSalle and DeSoto where cupped ventilating ports are incorporated. The Cord blunt V-shaped hood top extends down to six lower chromium-tipped louvres that run completely around the sides and front. The lower edge of the hood is flared outwardly to form a seventh louvre. Coolness in the front compartment is due to the exceptional hood ventilation provided.

Chevrolet provides two piano-type individual hinges integral with the plated center molding of the hood and forming integral drain troughs. A small door located under the hinged radiator ornament of the Nash "400" gives access to the water and oil filler caps.

Body

Most bodies are wider, increased leg and hood room is provided and the luggage compartment augmented in capacity. The convertible is staging a comeback. V windshields have been adopted by the Hudson, Terraplane, Studebaker and Cadillac and comprise fixed, single unit and double shield types. Slopes have been increased, Chevrolet using 31½ deg. and Cord 45 deg.

Cowls have increased bracing and are equipped in many cases with a toggle action control for the ventilator. There is greater use of box sections throughout and particularly for posts. In the Nash-Seaman bodies the cowl, windshield pillars and the front of the roof to the center door post form one

DeSoto Artistry

stamping to which the cowl sides are later welded. The rear side quarters and side roof corner panel to the center door post is one piece and later welded to a large stamping taking in the rear portions of the roof and the entire back panel. These two units are then welded together across the roof from side to side. The floor assembly and the center posts are next welded in place. The Studebaker roof panel stamping includes the cowl top, windshield section and runs back to include the rear window. The Cord body is built directly on its integral box section sills reinforced by x-members. Secondary box members run below the sills at the door openings. The top of the floor is 10⅜ in. above the ground, obviating the need of running boards. The sides above the belt line which is in the form of a radius have a decided inward taper. Overall height is 60 in.

All air entering the body in connection with the Hudson-Terraplane "year-round ventilation" is controlled and screened. A cloth screening member is placed over an opening in the body floor above the rear axle, which point was decided upon after many tests. As air is withdrawn by the suction produced on the windows in car movement, outside air enters through the "draft eliminator" since all possible leakage sources are sealed. The screen cloth balloons upward the instant a vacuum is created in the body.

The Cadillac cowl deck has a jute pad cemented to its underside and extends down as far as the truss member and the dash is insulated with thick jute and Celotex padding and fiber board. In the Studebaker a layer of Silento is cemented to the dash over which is fastened a liner of approximately 1 in. thickness composed of a layer of Silento and 45 layers of Kimsul and single corrugated board for fillers with a facing grained and colored to match the trim.

The conventional bodies of all Chrysler products are fastened directly to the chassis frame at the top and sides. Rubber composition pads insulate the body from the frame. In the entire Plymouth, exclusive of tires and tubes, there are over 400 rubber parts, which weigh 50 lb. The Hupmobile body with steel sills, pillars and floor is also secured to the frame rail by bolts in the top flanges and sides. The rear

floor pan is bolted to the x-member. Hardwood sills are used by Oldsmobile to dampen vibration. The framework around the rear quarter and rear windows is also of wood, serving as a foundation for the body trim.

Chevrolet, Pontiac, Oldsmobile, Packard "120" and Cadillac hinge the front doors at their forward edge, while Auburn, Hudson, Terraplane and Hupmobile retain their rear hinges. The Packard "120" top hinge is specially noteworthy, since the sloping lines and spaciousness provided by a rear hung door is retained. The lower hinge tips slightly inward, so that the top hinge center is within the curved cowl section and a rugged hinge shank runs to the pivot. Concealed hinges on the Cord are possible by a small gap between the door edges and center post. Mitchell Specialty Co. has developed a combination door dovetail and striker plate. The former is a heavy stamping while the pillar member consists of a specially treated die casting with two Superoilite wedges which are spring actuated and which push back on the door when it is closed. They take care of some vertical misalignment, compensate for wear and minor manufacturing tolerances and hold the doors securely to eliminate rattles and squeaks. They are used on the Chrysler products.

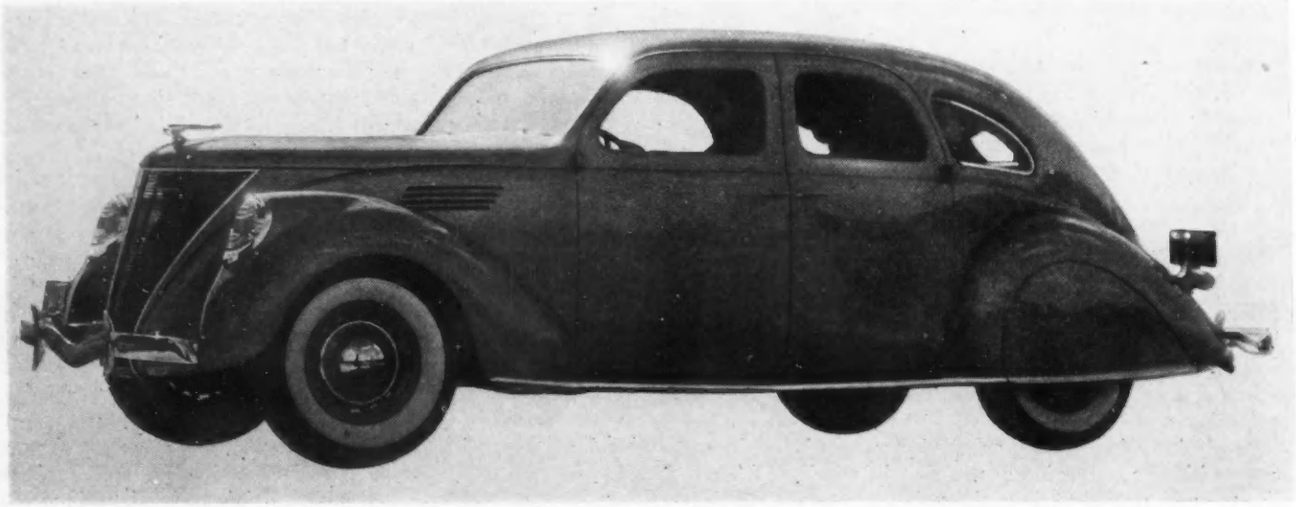
The DeSoto door handle is conspicuous by the addition of two eccentric arc decorations beneath it. Yale and Towne have developed a flush handle which is extended outwardly with the pressing of a button and is automatically withdrawn by the closing of the door. Their crushable pin tumbler lock in which it is possible to crush the tumblers to the proper key does away with the necessity of carrying large stocks of locks and keys. Interior hardware shows a wide usage of tenite in the form of knobs and inserts.

The bucket-type front seat on coupes is gradually disappearing. Chevrolets and Pontiacs have an adjustable full seat cushion extending the width of the car. The seat back is divided and the right section is hinged to fold forward. On the Chrysler products either half can be tilted forward. The Chrysler and DeSoto Airflows have, in addition to the customary fore and aft adjustment, a crank permitting the raising or lowering of either end of the seat. The Airflows and Nash Ambassador sedans have a center arm rest in the rear seat. The Pontiac and Chevrolet Master rear seat cushions extend all the way to the floor. A considerable number of cars have the footrest recessed into the back of the front seat.

Mohair and broadcloth predominate as upholstery material. The side walls are generally finished with the seat material and the head lining is colored to match the side walls. Cord chooses an English broadcloth in Banks Blue, Manchester Maroon or Seagreen to contrast with the one-color exterior of the car. Piping on the upholstery, including the arm rests and ceiling panel, is the same color as the exterior. On the Chevrolet seat cushions and backs, two wide vertical pleats are used, equally spaced between each other and the sides. Oldsmobile uses pillow-type trimming. Whipcord is used on the closed Cadillac "60" and in the touring sedan the front seat back is divided into two panels with three risers bordering the sides and top. The rear seat back is divided into three panel divisions. The vertical divisions are single risers and three risers are used for top and side borders. Near the top on the front of the rear cushion is a lace-covered welt. All doors are trimmed with double risers.

The all-steel top is used by Buick, Cadillac, Hudson and Terraplane as well as the Nash group which welds the body as previously described. Reo and the Chrysler group have an inserted body panel which is flanged to the French type steel roof by rubber insulated washers and dumdum. In this way it serves as a radio aerial. Asphaltic compound is sprayed on the Nash roof and side panels against which is cemented a waffle pattern felt followed by a loosely matted layer of soft fibers approximately 1 in. thick. A "muffler board" of fibrous material is cemented to the Hudson top beneath which are placed loosely, side by side, strips of masonite followed by loose, soft blue wadding. The Studebaker roof panel is sprayed with Insulmat to a thickness of 5/32 in. and baked 240 deg. Kimsul is cemented thereto by heat and pressure.

The increased capacity luggage compartments are usually finished off with chromium-plated ornamental bars. The single center handle on the Oldsmobile must be locked to remove the key. The Chrysler units are equipped with a cam type, theft-proof lock. The illuminated license bracket of the Chrysler Airflow is located in the center of the trunk cover which has a medallion ornament. When a trunk is to be installed on the Hudson, a protruding trunk door replaces the flush compartment lid giving 21 cu. ft. capacity with fender well tire mounting. On the Ford sedans the rear seat swings forward and down giving access to the luggage space.



The Lincoln-Zephyr has a V-12, 2¾ x 3¾ in. block-cast engine which develops 110 hp. at 3900 r.p.m. It has a 122-in. wheelbase and a streamlined unit body-frame structure mounted on transverse springs. The floor height is 12 in.

Evaluation of Variables Influencing Air Cooling of Engines

By Kenneth Campbell
Wright Aeronautical Corp.

TO convert cooling results observed under one set of conditions to equivalent values for other conditions, a better understanding of some of the many variables involved is needed. The progress of experiments being conducted along several lines with this objective in view is reported.

Published data on heat-transfer research have been examined and, from these, a working approximation relating air temperature and mass flow has been set up.

Single-cylinder engine and full-scale testing have been conducted to evaluate this equation as applied to modern baffling conditions.

Tests to observe directly the effect of cooling-air temperature-variation on cylinder-wall temperatures under specified conditions have been made.

The effect of carburetor-air temperature on cylinder-wall temperatures at constant manifold pressure has been experimentally determined.

A method of obtaining an indication of velocity through the baffle passages which is accurate under any condition of installation is described.

The volume of cooling-air flow through the baffle passages of a Cyclone engine is calibrated against readings of a baffle-flow indicator.

Other variables still require evaluation. The results obtained thus far are submitted for the use of others concerned with this problem.

FOR several years there has been a growing need for a means of converting cooling data obtained under one set of conditions to equivalent values under other conditions. It is frequently most inconvenient, if not prohibitively expensive, to simulate in test the conditions for which cooling information is desired. Cooling data obtained under widely differing conditions of cowling, flight operation, and climate, would be useful to engine manufacturers, to airplane builders and to transport operators, if the data could be rationally correlated by conversion to equivalent values for a standard condition of cooling practice. A better understanding of the many variables influencing cylinder-wall temperatures is necessary to the ultimate solution of the problem. The independent variables most vitally affecting cooling performance appear to be:

(1) Indicated horsepower per unit cylinder-wall area
(2) Fuel-air mixture-ratio
(3) Fuel-air mixture-temperature
(4) Design of cooling surface
(5) Design of baffling and cowling
(6) Cooling-air temperature
(7) Cooling-air velocity with respect to surface
(8) Cooling-air density

Much information on this general problem has already been contributed by other investigators. The matters of cowling, baffling, and design of cooling surfaces, have received the most thorough attention. This paper reports progress on additional experiments directed toward specific evaluation of some of the other variables, principally cooling-air temperature, velocity, and density, and combustion-air intake-temperature.

Single-Cylinder Test-Engine

In order that the numerous variables involved might be controlled with adequate precision, much of the laboratory testing has been done with a single-cylinder engine, the cylinder structure being typical of modern air-cooled aircraft-engine practice. Where feasible, supplementary work on multi-cylinder engines has been done to verify the indicated conclusions, and flight tests are now being conducted.

The single-cylinder engine used for the laboratory tests incorporates a cylinder of a Wright Whirlwind; 5-in. bore,

[This paper was presented at the Semi-Annual Meeting of the Society, White Sulphur Springs, West Va., June 17, 1935.]

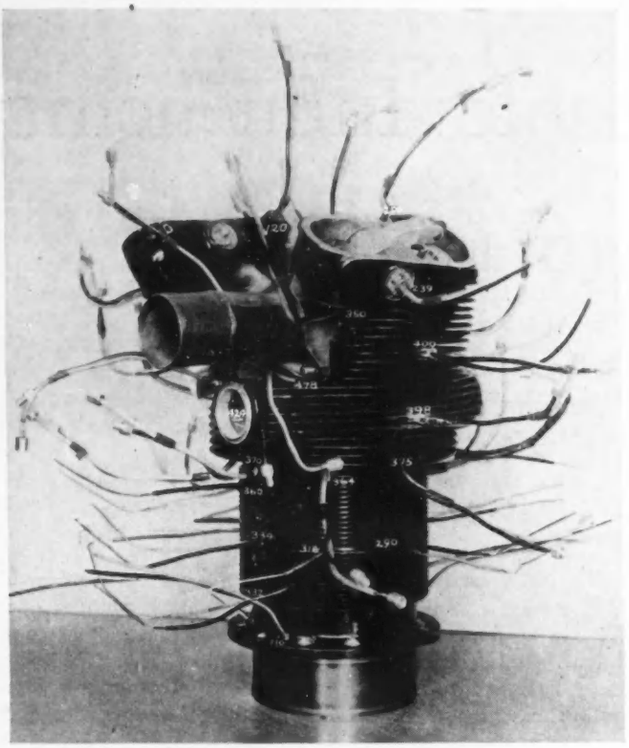


Fig. 1—Rear Exhaust-Side of the Cylinder Assembly

5½-in. stroke; 7:1 compression ratio. The engine is naturally aspirated and at full throttle develops a specific output of about 0.46 hp. per cu. in. Means of regulating and measuring fuel-air ratio, carburetor-air temperature, cooling-air temperature, cooling-air velocity, and oil temperature are, of course, provided.

While the limiting operating temperature in an engine is usually that of the piston, on radial air-cooled engines the spark-plug-gasket temperatures have come into general use as indicators of the variation of critical temperatures. For these tests, it was not practicable to obtain piston temperature, but temperature variations all over the cylinder assembly were carefully measured, and for this purpose 36 thermocouples were employed.

A view of the cylinder assembly is shown in Figs. 1, 2 and 3. The baffles were made as nearly as possbile according to the recommendations of Beisel, MacClain and Thomas[1]. There was no propeller in the dynamometer-test installation, and it was therefore necessary to provide an increased velocity over the front half of the cylinder in order to operate at high power-output and to obtain a normal relation between front and rear temperatures, since this portion of the assembly was not covered by the baffles. The air was directed toward the cylinder through a nozzle of rectangular cross-section. The front and rear views of the installation are shown in Figs. 4 and 5.

Review of Published Data

The basic principles of the relation of air density, velocity, and temperature, to surface temperatures have already been established, thanks to much laboratory research on heat transfer during the last 30 years. There is considerable experimental evidence that a heat-transfer equation credited to Bossinesq[2] in 1905 and independently arrived at by Nusselt[3] in 1909 approximates the truth both for turbulent[4], and for laminar[5], airflow. By limiting the variables to density, velocity and air temperature, the equation becomes sufficiently simple for useful application.

Assuming a constant rate of heat disposal, as approximated in an engine by maintaining constant indicated horsepower and other internal operating conditions, the equation may be written in terms of wall temperature, as follows:

$$t_w = t_a + C \cdot \frac{\mu^x}{k} \cdot \frac{1}{(\rho V)^x}$$

where

t_w = wall temperature
t_a = air temperature
μ = absolute viscosity of air at mean of surface and air temperature
k = thermal conductivity at mean of surface and air temperature
ρ = air density
V = air velocity
C = a constant depending on the units used

The experiments of Reiher[6] and of Dittus and Boelter[7], indicate that μ, ρ, and V, all have the same exponent. Thus ρ and V may be written as shown, their product representing the mass flow.

The variable of air temperature is represented in the foregoing equation not only by the term t_a but by its effect on the value of the term μ^x/k. The viscosity μ and the conductivity k for air both vary in known relation with temperature. Density variation alone, over the range applying to this problem, does not affect μ and k more than a negligible amount. The experimental data indicate, however, that the value of the term μ^x/k applicable to the equation is determined by the mean of surface and air temperatures. The value of the term is therefore partly dependent on the cooling-air temperature, and partly on the temperature of the surface in contact with the air. The variation of this term with respect to air temperature alone will therefore not be the same for all problems. The maximum effect of this term should be an increase of 5 to 7 per cent in the temperature difference between wall and air, per 100-deg. fahr. decline in cooling-air temperature. The term can therefore well be isolated and added as a correction to the results after the wall temperature has first been approximated by the equation containing the other factors.

The essential requirement for useful application of the equation is the determination of the value of the exponent x.

Published experimental values are somewhat confusing, varying from 0.4 to 0.8, with many intermediate values observed. The N.A.C.A. has been an outstanding contributor

[1] See *S.A.E. Transactions*, 1934, pp. 147-166; "The Cowling and Cooling of Radial Air-Cooled Aircraft-Engines," by Rex B. Beisel, A. Lewis MacClain and F. M. Thomas.
[2] See *Industrial and Engineering Chemistry*, 1922, vol. 14, p. 1101; "Heat Transfer by Conduction and Convection," by W. H. McAdams and T. H. Frost.
[3] See Industrial Heat Transfer, by Alfred Schack, 1933, for W. Nusselt's equations, pp. 64-70 and 98-100; J. Wiley & Sons, Inc., New York City.
[4] See Industrial Heat Transfer, by Alfred Schack, 1933, for Reiher's experiments, pp. 122-130; J. Wiley & Sons, Inc., New York City.
[5] See University of California Publications in Engineering: Dittus, Vol. 2, No. 11; Dittus and Boelter, Vol. 2, No. 13.
[6] See Industrial Heat Transfer, by Alfred Schack, 1933, for Reiher's experiments, pp. 122-130; J. Wiley & Sons, Inc., New York City.
[7] See University of California Publications in Engineering; Dittus and Boelter, Vol. 2, No. 13.

to the problem as applied to air-cooled cylinders[8]. The nature of the flow—laminar or turbulent—appears to be the most important factor influencing the value of the exponent. One possible explanation of the great divergence of exponents observed is that the intermediate values may be due to the simultaneous existence of both laminar and turbulent flow at different areas of the heat-transfer specimen under test. The shape and dimensions of the air-path boundaries, and the initial turbulence of the air, influence the type of flow.

Experimental Evaluation of the Equation

For comparison with available data[8], a series of runs was made on the single-cylinder engine to determine the value of the exponent x for the particular baffles and fins of this installation. The mass flow was varied by changing the velocity through the baffles while keeping the air temperature constant. The brake horsepower, number of revolutions per minute, carburetor-air temperature, fuel-air ratio and oil inlet-temperature, were maintained constant during each run. The exponent x could then be determined by the conventional method of logarithmic plotting of the temperature difference versus the mass flow—velocity in this case—the slope of the straight line obtained being the exponent. Data were obtained in this manner for several runs at different horsepowers, readings being obtained for 15 thermocouples about the combustion chamber, barrel-top and mid-barrel. Typical data for four runs at differing horsepowers are shown plotted in Fig. 6 for six of these thermocouples.

[8] See N.A.C.A. 1934 Technical Report No. 488; Biermann and Pinkel. See also N.A.C.A. 1932 Technical Note No. 429; Schey and Biermann. See also N.A.C.A. 1930 Technical Note No. 331; Taylor and Rehbock.

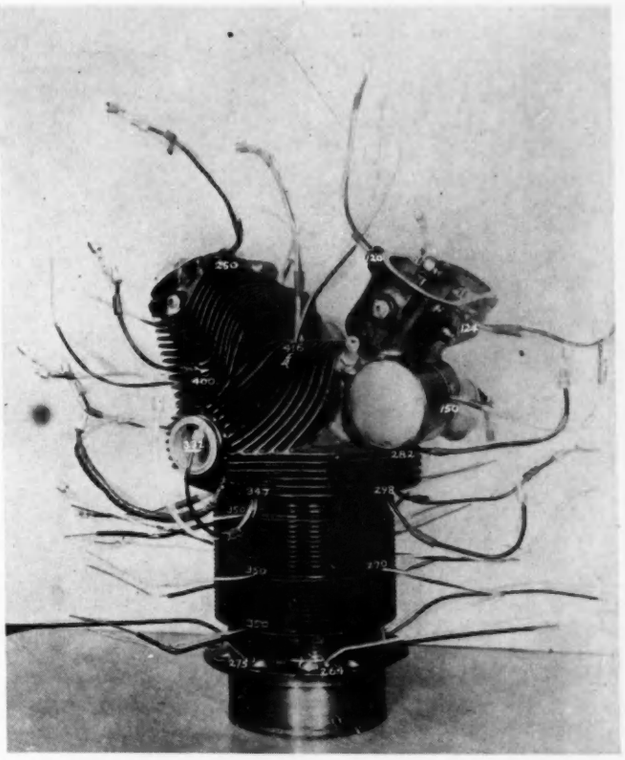


Fig. 3—Front Intake-Side of the Cylinder Assembly

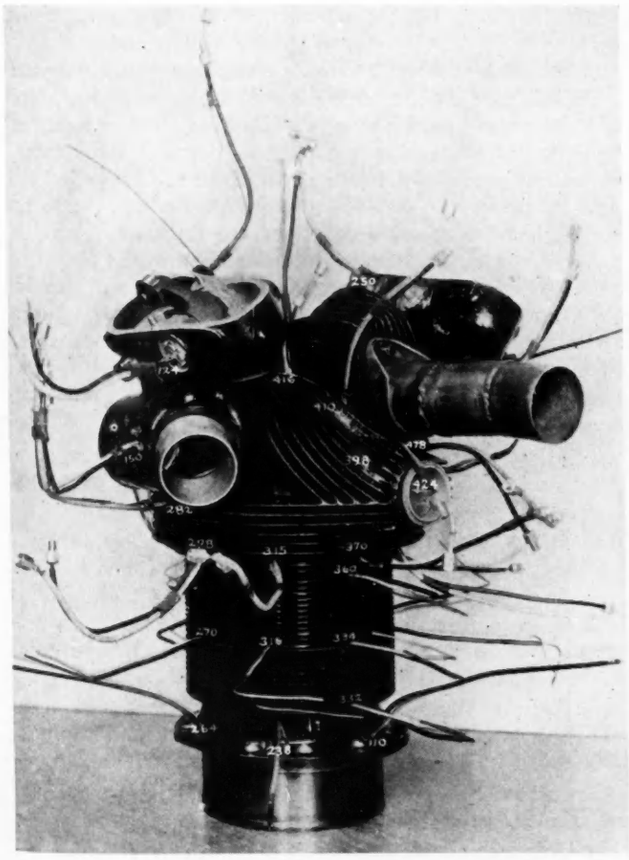


Fig. 2—Rear Intake-Side of the Cylinder Assembly

The exponent at most thermocouple locations, particularly about the combustion chamber, proved to be about 0.5; but it was definitely shown to be less than this value at some barrel locations, and in one case it was 0.4.

Subsequent tests were made on a Cyclone engine on a blower-cooled dynamometer-stand, the points of temperature observation being limited to front and rear spark-plug gaskets. The engine was delivering powers from 400 to 800 hp., and the baffle pressure-drop was varied from 21 in. to 3 in. of water. Data exactly similar to those shown were obtained, and the value of the exponent x varied between 0.4 and 0.5.

Comparing these results with the early N.A.C.A. publications giving an exponent of 0.8 for unbaffled finned cylinders, it appears that the baffling used had a critical effect on the exponent. Probably the reduced cross-section of the air path relative to perimeter reduces the Reynolds number below a critical value, causing laminar flow over most, though possibly not all, of the fin width. The question arises as to whether the turbulence behind the propeller in flight will cause a higher exponent to prevail.

Assuming then, an exponent of 0.5, it was possible to set up for further check a tentative formula for approximating wall temperatures at one set of air density, velocity, and temperature conditions, from temperatures observed under other conditions of test.

First Approximation.—Effect of mass flow and air-temperature variation.

$$t_{w_2} = t_{a_2} + t_{D_1}\left(\frac{\rho_1 V_1}{\rho_2 V_2}\right)^{0.5}$$

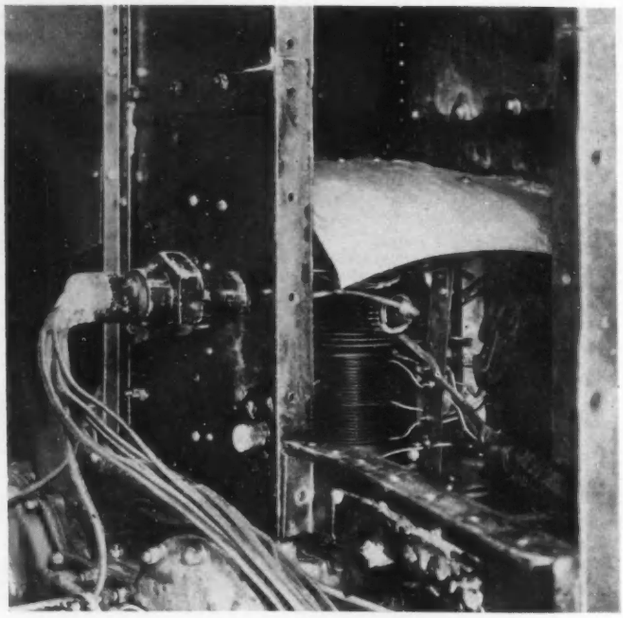


Fig. 4—Front Right View of the Installation as Revised for Cooling Tests

Second Approximation.—Effect of mean-temperature variation.

$$t^1_{w_2} = t_{w_2} + 0.05 t_{D_1} \left(\frac{t_{w_1} - t_{w_2} + t_{a_1} - t_{a_2}}{200} \right)$$

where

1 and 2 refer to the two sets of conditions

t_w = wall temperature, deg. fahr.

t_a = air temperature, deg. fahr.

t_D = temperature difference, wall to air, deg. fahr.

This formula requires flight testing to adjust both the value of the exponent and the magnitude of the second approximation for a given installation. As indicated, such a formula assumes constant indicated horsepower and other internal operating conditions influencing wall temperature, as well as absence of detonation.

The general nature of the results when applying such a formula to an hypothetical case of constant-power climb at constant indicated horsepower, such as could be approximated by use of an engine with an exhaust-turbine-driven supercharger and intercooling, is of interest. Analyzing a curve by Allen and Oswald[9], it appears that the airspeed of a Douglas DC-2 airplane in constant-power climb maintained at best climbing angle increases approximately inversely as the 0.6 power of the density. Assuming this relation to be correct, Fig. 7 shows the calculated variation of wall temperatures with increasing altitude for several initial wall temperatures. The values are computed for exponents of 0.5 and 0.8. The fact that the higher wall temperatures increase with altitude while the lower temperatures decline appears to be logical, though the quantitative results are, as pointed out, calculated for a particular set of operating conditions. If the airspeed is varied in a different relation with altitude than that assumed, the cylinder-wall temperature-variation will of course be different from the variation calculated here. In this problem the two principal components determining change in wall temperature with increasing altitude are (*a*) effect of declining mass flow on temperature difference, and (*b*) effect of declining cooling-air temperature, and the two components oppose each other. For high temperature-differences, factor (*a*) is the larger in degrees, resulting in a net increase of wall temperature with altitude while, for small temperature-differences, factor (*b*) is the more important, resulting in a net decline.

To check the values of x found for blower-cooled engines in the laboratory, flight testing is now being conducted, and some interesting results have been obtained. The equipment used for this purpose is a Fairchild "Pilgrim" monoplane, powered by a cowled Cyclone engine with standard Cyclone baffling, having a 10 to 1 supercharger gear-ratio, a 16 to 11 propeller gear-ratio, and a constant-speed propeller. A valve has been inserted in the pitch-control oil-line to the propeller so that, when closed for a short interval, the pitch will remain fixed long enough to determine the best power-setting by loss of number of revolutions per minute. An electrical exhaust-gas tester is also helpful in checking the best power-setting or in adjusting the mixture ratio with respect to that point. The general method of testing is as follows:

(1) Fly level at constant r.p.m. at several altitudes

(2) Vary the mixture ratio from rich to lean past the point of maximum-power setting, for each run

(3) Start the tests at full throttle at the highest altitude scheduled

(4) At each successively lower altitude-level, adjust the manifold pressure upward an amount just sufficient to restore that portion of the horsepower decline which influences cylinder-wall temperatures

(5) For each mixture-setting, record all front and rear spark-plug-gasket temperatures and all engine and cooling conditions.

The loss of horsepower with decline in altitude at constant manifold pressure is due to five major causes:

(1) Decreased charge due to increased exhaust pressure

(2) Decreased power absorbed by the supercharger

[9] See *Aviation*, November, 1934, p. 263, Fig. 36; Allen and Oswald.

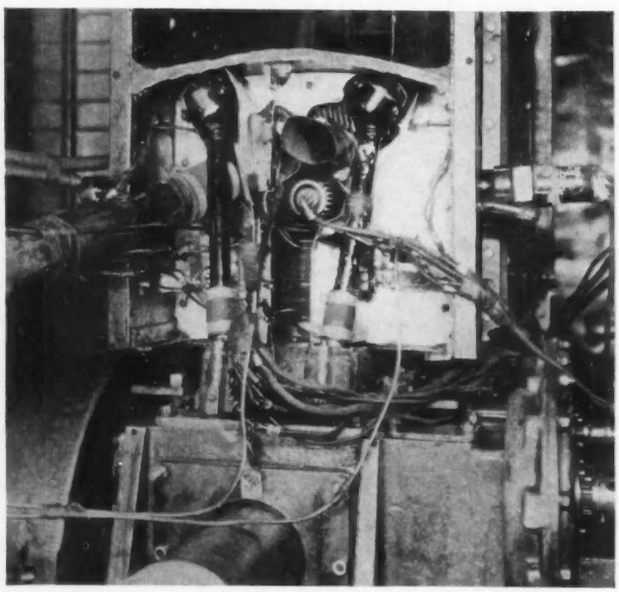


Fig. 5—Rear View of the Installation

Table 1—Flight-Test Conditions for the Study of Altitude Cooling-Performance. Equipment: Fairchild Pilgrim with SGR-1820-F-54 Engine. Compression Ratio, 6.4:1; Supercharger Gear-Ratio, 10:1; Propeller Gear-Ratio, 16:11; and Constant-Speed Propeller.

Operating Conditions					
Pressure Altitude, ft.	17,500	14,000	10,500	7,000	2,500
Carburetor Air-Temperature, deg. fahr.	18	30	42	55	76
Mixture Temperature, (adapter) deg. fahr.	−10	0	+5	+10	+22
Mixture Temperature, (No. 1 manifold) deg. fahr.	140	135	140	145	155
Engine Speed, r.p.m.	1,850	1,850	1,850	1,850	1,850
Manifold Pressure, in. of mercury (absolute)	27.1	27.4	27.7	28.1	28.6
B.Hp. plus Supercharger Hp. (calculated), Hp.	562	547	536	530	514
Indicated Airspeed, m.p.h.	149	141	130	124	116
Baffle Pressure-Drop, in. of water	4.5	4.5	4.7	4.8	5.0
Baffle-Flow Indicator, in. of water	3.7	3.7	4.0	4.0	4.2
Cooling-Air Temperature, deg. fahr.	12	24	33	45	65
Oil-Inlet Temperature, deg. fahr.	160	155	160	160	170

Note: For each run, the mixture ratio was varied from rich to lean through the point of maximum power. The throttle was wide open at 17,500 ft. The manifold pressure was adjusted at other altitudes to give a horsepower decline approximating a condition of constant heat-dissipation through the cylinder walls.

(3) Decreased charge due to increased carburetor-air temperature

(4) Decreased work done on the pistons on the intake stroke

(5) Change in friction horsepower.

Only causes (1) and (2) influence cylinder-wall temperatures appreciably at constant r.p.m., as discussed later under the heading "Tests on the Effect of Carburetor-Air Temperature". Hence, to approximate constant heat-disposal through the cylinder walls as altitude decreases, only these two components of loss should be restored by upward adjustment of the manifold pressure.

The conditions of an actual flight test recently made are shown in Table 1, starting at an altitude of 17,500 ft. and adjusting the manifold pressure at each altitude by means of previously prepared curves and forms for computation. For best-power mixture-setting at each level, the observed average and maximum rear spark-plug-gasket temperatures are shown plotted against altitude in Fig. 8.

Taking the observed gasket temperature at 2500 ft. and the observed air temperatures and air velocities through the baffle passages at all the altitudes, we may calculate the variation of gasket temperature with altitude according to the proposed equation. The most interesting result is that, using the previously expected exponent of 0.5, the calculated temperatures deviate widely from observed values; while, using an exponent of 0.8, corresponding to turbulent flow, the observed and calculated altitude-temperature curves give satisfactory correlation.

Examination of the observed altitude-temperature curves of

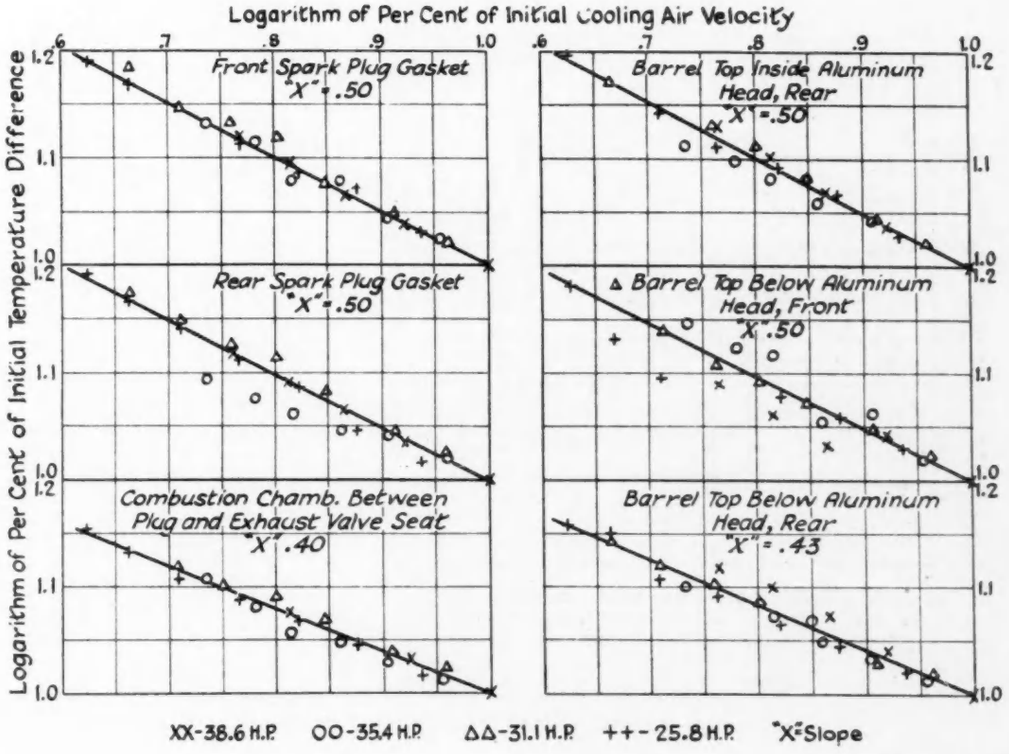

Logarithm of Per Cent of Initial Cooling Air Velocity
Logarithm of Per Cent of Initial Temperature Difference
.6
.7
.8
.9
1.0
1.2
1.1
1.0
Front Spark Plug Gasket "X" = .50
Barrel Top Inside Aluminum Head, Rear "X" = .50
Rear Spark Plug Gasket "X" = .50
Δ Barrel Top Below Aluminum Head, Front "X" = .50
Combustion Chamb. Between Plug and Exhaust Valve Seat "X" = .40
Barrel Top Below Aluminum Head, Rear "X" = .43
XX-38.6 H.P. OO-35.4 H.P. ΔΔ-31.1 H.P. ++-25.8 H.P. "X"=Slope

Fig. 6—Determination of the Exponent *X* for Six Locations on the Cylinder

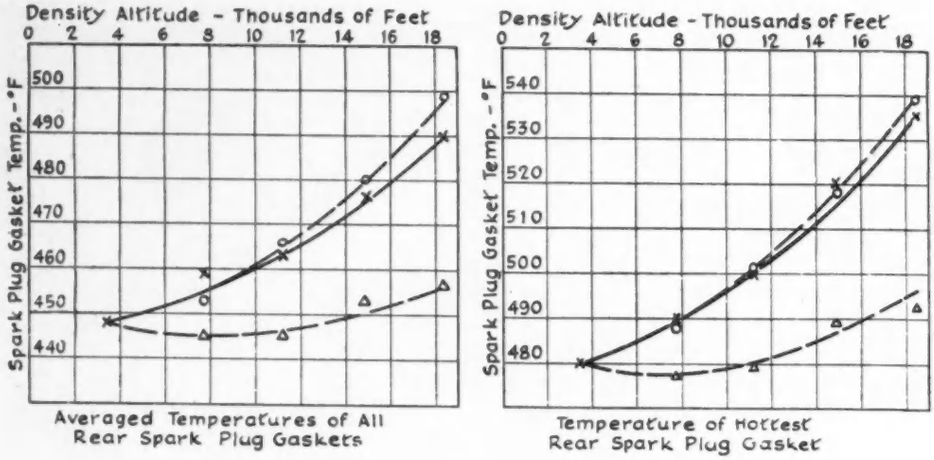

Density Altitude - Thousands of Feet
0 2 4 6 8 10 12 14 16 18
Spark Plug Gasket Temp. - °F
500 490 480 470 460 450 440
Averaged Temperatures of All Rear Spark Plug Gaskets
Density Altitude - Thousands of Feet
0 2 4 6 8 10 12 14 16 18
Spark Plug Gasket Temp. - °F
540 530 520 510 500 490 480
Temperature of Hottest Rear Spark Plug Gasket

Fig. 8—Variation of Rear Spark-Plug-Gasket Temperatures with Altitude

For flight-test operating-conditions see Table 1.

Observed gasket temperatures are indicated by X; the calculated gasket temperatures, using $x=0.8$, by O; and the calculated gasket temperatures, using $x=0.5$, by Δ

The chart shows a comparison of the observed variation of gasket temperatures with the calculated variation, based on the observed cooling-air temperatures and velocities at the several altitudes. All temperatures shown are for the best-power mixture-setting.

the individual rear gaskets showed that they were consistent in their general shape. This was not the case for the observed front spark-plug-gasket-temperature curves, which differed widely in shape. In all cases, however, the front temperatures were well below the corresponding rear temperatures and showed no greater rise with increasing altitude.

Variable Cooling-Air-Temperature Experiments

Information frequently required is the effect of cooling-air temperature-variation on cylinder-wall temperatures when flying at a given altitude and manifold pressure. A series of runs was made on the single-cylinder engine to obtain a direct experimental answer to this problem. Under the assumed conditions of constant altitude and manifold pressure, the variation of airspeed—taking into account the effect of air temperature on both power and drag—was assumed to be approximately proportional to the 1/6 power of the absolute temperature. For a 100-deg. increase of cooling-air temperature, the airspeed, and the relative cooling-air velocity, should therefore increase only about 3 per cent. For the tests, the velocity was held approximately constant as air temperature was varied. The cylinder-wall temperatures were therefore affected by variation of air temperature and density. Thirty-one thermocouple readings were taken for each value of cooling-air temperature. Four of the runs were made at nearly identical values of constant manifold pressure, carburetor-air temperature, fuel-air ratio, r.p.m., and oil-in temperature. The readings for each thermocouple were then plotted against entering-air temperature for the four runs.

Six of the 31 curves thus obtained are shown in Fig. 9, with entering cooling-air temperature plotted as abscissas against thermocouple readings as ordinates. Grouping the data for all the curves obtained according to similar slopes, and averaging the readings within each group, the curves shown in Fig. 10 were obtained. The deviation of slope between the curves of any group was, with few exceptions, small.

Inspection of these data leads to the following conclusions:

(1) Variation of wall temperature with cooling-air temperature at constant altitude and manifold pressure is approximately linear.

(2) Variation of wall temperature with cooling-air temperature is dependent on the relative location of the thermocouples axially on the cylinder assembly.

Curves *A*, *B* and *C* of Fig. 10 represent averaged data for the combustion chamber, barrel-top, and mid-barrel wall-temperatures, respectively. Substituting into the equation previously suggested the values of these curves for cooling air of 20 deg. fahr., calculations may be made of the wall temperatures to be expected for air temperature at 120 deg. fahr.

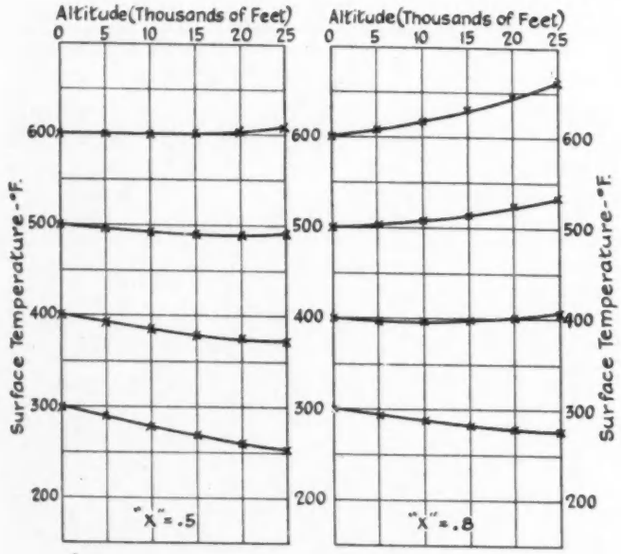

Altitude (Thousands of Feet)
0 5 10 15 20 25
Surface Temperature - °F.
600 500 400 300 200
"X" = .5
Altitude (Thousands of Feet)
0 5 10 15 20 25
600 500 400 300 200
"X" = .8
Surface Temperature - °F.

Fig. 7—Illustration of the Effect of the Exponent *X* and of the Initial Surface Temperature on the Calculated Temperature-Variation of the Surface with Altitude

The calculation for an hypothetical case is as follows: Constant-power climb; best climbing angle maintained, $[V \sim (1/\rho)^{0.6}]$; constant indicated horsepower; and standard air-temperature variation from sea-level air-temperature of 100 deg. fahr.

For Cooling Air at 120 Deg. Fahr.	Group *A*, Combustion-Chamber Walls, Deg. Fahr.	Group *B*, Combustion-Chamber Walls, Deg. Fahr.	Group *C*, Mid-Barrel Walls, Deg. Fahr.
Observed Wall Temperatures	438	379	356
Calculated Wall Temperatures, (exponent $x = 0.5$)	435	388	363

The agreement of calculated with observed temperatures is close for the group of 10 combustion-chamber thermocouples (Group *A*), but is less satisfactory for the barrel groups. This may be due to the fact that the barrel showed a slightly lower value of the exponent x than the value of 0.5 used in the computation.

Fig. 11 compares the slopes of the average curves of the different groups. The average temperature of the combustion-chamber walls (Group *A*) rose 114 deg. fahr. per 100-deg. fahr. air-temperature increase. The exhaust rocker-box temperatures, though lower, increased 131 deg. fahr. as an average. Fig. 12 shows the same data expressed in terms of the percentage of temperature difference between wall and entering air for a cooling-air temperature-increase of 100 deg. fahr. The temperature difference at the combustion chamber increased 5 per cent. That at the barrel-top and mid-barrel increased only 2 per cent, again indicating a somewhat reduced exponent below that of the combustion chamber.

The large increase of temperature difference at the two rocker boxes, 18 per cent at the exhaust and 12 per cent at the intake rocker-box, is at variance with the other groups. The declining temperature difference at the lower barrel and flange may be due to an increase of heat conduction to the oil and crankcase masses as barrel temperatures increased. This condition is, probably, not typical of radial-engine flight-conditions.

A record of the distribution of temperature over the entire cylinder assembly, for this particular installation, was made possible by the large number of thermocouples installed. Marked on Figs. 1, 2, and 3, are typical temperatures, observed under stable conditions, at the locations indicated. The thermocouple location showing the highest temperature (478 deg. in Fig. 1) was the combustion-chamber wall between the rear spark-plug recess and the exhaust-valve seat. This temperature was consistently found to be about 50 deg. fahr. higher than that of the rear spark-plug gasket. The exhaust valve-guide-boss temperature ran slightly lower than the rear spark-plug gasket. The temperatures of the exhaust valve-spring seat and exhaust rocker-pin (350 and 239 deg. fahr. in Fig. 1, respectively) are of interest.

Tests on the Effect of Carburetor-Air Temperature

The most severe cooling requirements are, of course, at maximum allowable manifold pressure, and in common practice this specified pressure is not adjusted for changes in carburetor-air temperature. Also, turbo-type superchargers equipped with constant manifold-pressure regulators cause a variation in mixture temperature with altitude. Understanding of the effect of carburetor-air temperature on cylinder-wall temperature at constant manifold pressure is therefore desirable for cooling correlation. Tests to determine this effect were made first on the single-cylinder engine and then on a full-scale Cyclone-engine under non-detonating conditions.

The single-cylinder tests consisted of a series of runs in which fuel-air ratio was varied while carburetor-air temperature was held constant. The manifold pressure at maximum power was adjusted to the same value for each run, but the constant carburetor-air temperature was changed for each run. The cooling-air temperature (and density), velocity, the r.p.m., and the oil-in temperature were maintained constant for each run and closely alike for all the runs. Fig. 13 compares the combustion-chamber wall-temperatures obtained for carburetor-air temperatures of 50, 130, and 212 deg. fahr., at a constant manifold pressure. The wall temperatures under these conditions varied only 15 deg. maximum for the same fuel-air ratio; and, for maximum-power fuel-air ratios—corresponding to similar points on the power curves—the wall-

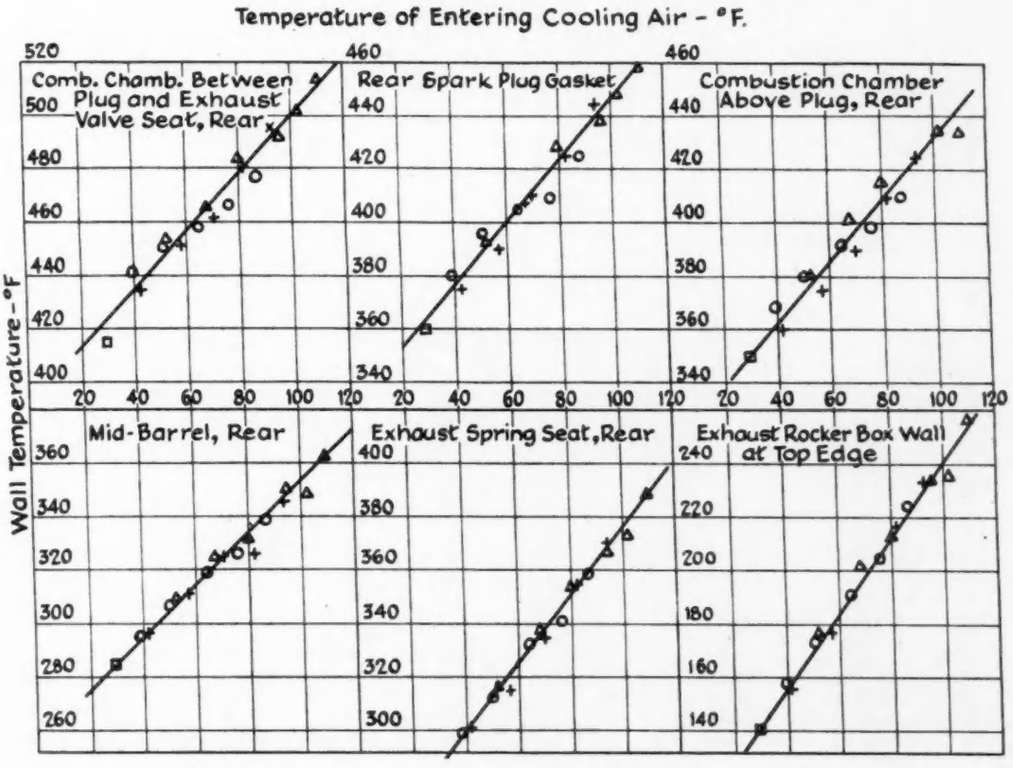

Temperature of Entering Cooling Air - °F.
Wall Temperature - °F
Comb. Chamb. Between Plug and Exhaust Valve Seat, Rear
Rear Spark Plug Gasket
Combustion Chamber Above Plug, Rear
Mid-Barrel, Rear
Exhaust Spring Seat, Rear
Exhaust Rocker Box Wall at Top Edge

Fig. 9—Cylinder-Wall - Temperature Variation with Cooling-Air Temperature at Six Thermocouple Locations

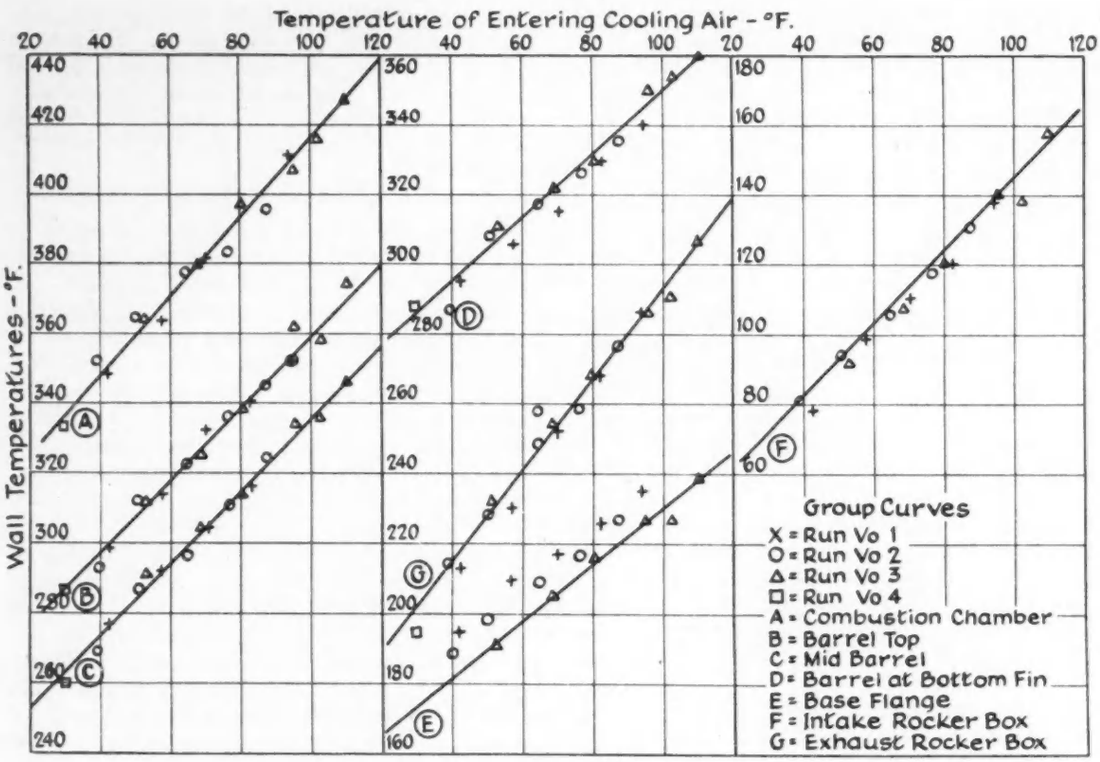

Temperature of Entering Cooling Air - °F.
Wall Temperatures - °F.
Group Curves
X = Run Vo 1
O = Run Vo 2
Δ = Run Vo 3
□ = Run Vo 4
A = Combustion Chamber
B = Barrel Top
C = Mid Barrel
D = Barrel at Bottom Fin
E = Base Flange
F = Intake Rocker Box
G = Exhaust Rocker Box

Fig. 10—Variation of Cylinder-Wall Temperature with Cooling-Air Temperature at Constant Velocity, the Data Being Averaged for Each Location Grouping

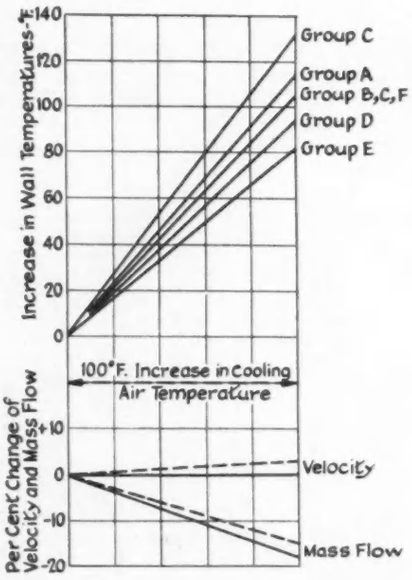


Fig. 11—(*Left*) Observed Effect of Entering Cooling Air Temperature on Cylinder-Wall Temperatures for the Flow-Variation Shown.

The dashed lines indicate flow-variation for flight at constant manifold pressure and altitude.

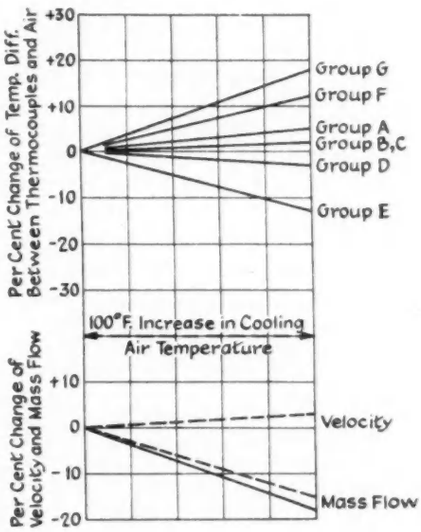


Fig. 12—(*Right*) Observed Effect of Variation of Cooling-Air Temperature on the Temperature Difference between Thermocouples and Air

Group	Specification	Number of Thermocouples
A	Combustion Chamber and Exhaust Port	10
B	Barrel Top Inside of Aluminum Head	5
C	Mid-Barrel	4
D	Barrel at Bottom Fin, Rear	1
E	Base Flange	4
F	Intake Rocker-Box Wall and Pin	2
G	Exhaust Rocker-Box Wall, Pin and Spring Seat	3

Group	Specification	Number of Thermocouples
A	Combustion Chamber and Exhaust Port	10
B	Barrel Top Inside of Aluminum Head	5
C	Mid-Barrel	4
D	Barrel at Bottom Fin, Rear	1
E	Base Flange	4
F	Intake Rocker-Box Wall and Pin	2
G	Exhaust Rocker-Box Wall, Pin and Spring Seat	3

temperature variation was negligible. Subsequent tests on a Cyclone engine on a test stand confirmed these conclusions, provided, of course, carburetor-air temperatures were not so elevated as to induce detonation.

Standardization of Baffle-Flow Measurement

One variable which needs to be checked before air-cooling performance-data can be rationally correlated is the choice of means for indicating velocity through the baffle passages. The conventional method at present is to observe the static-pressure drop from front to rear of the engine. To make a sound comparison between two sets of data on this basis, two conditions must be fulfilled: (*a*) the static-pressure measuring-devices must be reasonably accurate in both cases; and (*b*), the distribution of flow through the passages on the two sides of the cylinder must be comparable in the two cases.

Tests with a Cyclone engine with a propeller on a fixed stand show clearly that under such conditions the strong tangential component of airflow in front of the engine due to the propeller has the following effects: (*a*) it causes the conventional closed-end static-tube in front of the engine to read far below the true static pressure; (*b*) it causes the flow

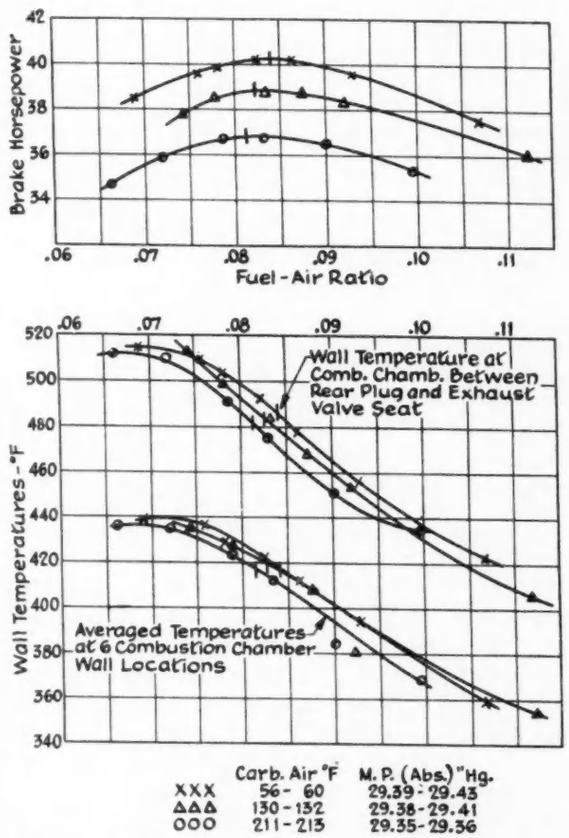


Fig. 13—Effect of Carburetor Air-Temperature Variation at Constant Manifold Pressure on Combustion-Chamber Wall-Temperatures

through the baffle passages to be much higher on the side which the blades approach.

Tests made with the objective of developing a standard method of baffle-flow measurement which will give a true indication of flow through the baffle passages under any conditions of flight or engine-laboratory installation have produced some results. One means of reliably indicating velocity through the baffle passages has proved fairly satisfactory. This consists of an impact tube and separate static disc fastened to the inside surface of a baffle, as shown in Figs. 14 and 15. These devices can be used as a basis for checking other methods of flow indication, and also for studying distribution of flow about the cylinder. The impact tube is tapered to a sharp edge at the rear, and its forward face is tilted 7 deg. from the normal to the baffle so as to be approximately normal with the center line of the baffle passage. The impact tube is 1 in. long, 3/32 in. wide and about ¼ in. high at the face. The static disc is of polished steel, 0.015 in. thick, with thin edges. A 0.020-in. hole is drilled in its center.

An improved static-pressure measuring-tube—suitable for experimental work—has also been used. This has much less error than the conventional closed-end static-tube with side holes when subjected to strong cross-currents. It consists of a hollow, polished, brass disc with rounded edges, about 1¾ in. in diameter with a 0.020-in. hole in the center of each face. Attached radially to one edge is a metal tube. When placed in an airstream of unknown direction, the error is less for any position of the disc than for a closed-end static-tube crosswise to the stream, and if the disc be turned by rotating its tube until a maximum pressure is recorded, the error becomes very small.

These devices have recently been applied in flight tests to check the variation of baffle-pressure drop, as measured by closed-end static-tubes, against true static-pressure drop and against velocity head in the baffle passages. The "Pilgrim" airplane previously described was used, but operating with a fixed-pitch propeller.

The closed-end static-tubes were each of 3/16 in. outside diameter, with rounded tip and with a ring of 12 side holes 0.020 in. in diameter located 1 in. from the tip. The forward tube projected through an intercylinder baffle 1½ in. at barrel-top height. The rear tube was directly behind the same baffle at the same height.

The front and rear disc static-tubes terminated at planes coincident with the front and rear spark plugs respectively, at combustion-chamber height and midway between two cylinders. The pairs of baffle-flow indicator-devices were located on both sides of the cylinders at barrel height and at combustion-chamber height.

Pressure readings of the various devices taken for several relationships of propeller speed to airspeed, including readings at 1950 engine r.p.m. at 100 m.p.h., showed that there

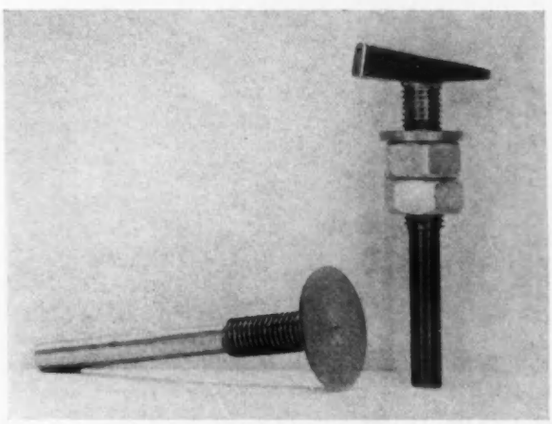


Fig. 14—Impact Tube and Static Disc

was no measurable tangential component of airflow in front of the engine in flight. The velocity was the same past both sides of the cylinders, and the closed-end static-tubes indicated the true static pressures prevailing. For this geared engine, baffling and cowling installation, measurement of baffle-pressure drop by the closed-end static-tubes described gave a true indication of the variation of velocity pressure in the baffle passages. Similar experiments conducted with a direct-drive installation would be desirable.

Measurement of Cooling-Air Flow

Information is frequently desired, particularly by aircraft designers, as to the quantity of cooling air passing through an engine under various cooling conditions: By careful calibration of a cooling blower for an engine test-stand, the airflow through the baffle passages of any radial engine is obtainable. Fig. 16 shows, plotted against differential readings of the impact-static baffle-flow device described, the cooling-air flow in cubic feet per minute through the baffle passages of a Cyclone engine. The flow-indicating devices were located on the exhaust side at combustion-chamber level, with the static disc at the rear edge of the baffle and the impact tube about 4 in. forward.

This information may be utilized to calculate, for the engine and baffling, a cooling-performance yardstick originated by the N.A.C.A. This is the theoretical horsepower required to force the cooling-air volume against the resistance, or baffle pressure-drop, of the baffle passages. The airstream horsepower is expressed in percentage of brake horsepower developed by the engine.

In engine-laboratory tests to determine the best cooling performance of a Cyclone measured on this basis, 800 b.hp. was developed with a baffle pressure-drop of 3 in. of water for a

Fig. 15—Impact Tube and Static Disc Fastened to the Inside Surface of a Baffle

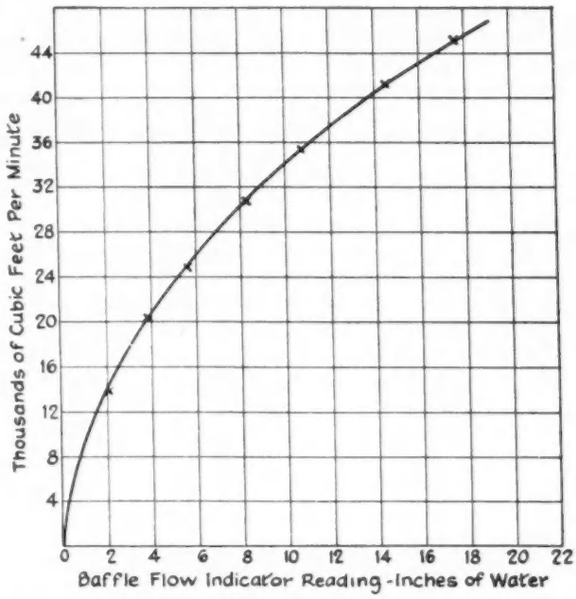


Fig. 16—Flow Through the Baffle Passages of a Cyclone Engine at Sea Level for Any Reading of the Baffle-Flow Indicator

period of 10 min., resulting in a maximum spark-plug-gasket temperature of 470 deg. fahr. The entering cooling-air temperature was 57 deg. fahr. and the specific fuel consumption was 0.50 lb. per b.hp-hr. Gasoline of 87 octane number was used.

The theoretical airstream power is 8.5 hp. in this case, or just over 1 per cent of the brake horsepower developed by the engine. At 5 in. of baffle pressure-drop, a conservative cooling condition, the performance figure becomes 2.2 per cent. These performances appear to be very favorable. It should be noted that while—from the volume curve shown—the volume flowing through the passages is relatively high, the cooling is accomplished at baffle pressure-drops which are low. Satisfactory cooling at low baffle pressure-drops is desirable and efforts have been expended for some time with this end in view. The most severe cooling requirements occur in climbing, and because of the relatively low airspeeds prevailing for this condition, the baffle pressure-drop available to work with is limited, unless additional equipment is provided to augment it.

Conclusion

As is indicated by the list of variables shown at the beginning, there are several, especially, indicated horsepower per unit cylinder-wall area, which still require evaluation for cooling-correlation purposes. These are not discussed in this paper.

The results obtained thus far are presented to assist in the development of methods for predicting cooling performance under conditions not readily available in test, or for the reduction of observed cooling performance to equivalent performance for a standard set of conditions. It is hoped that these data will be helpful to others concerned with cooling problems.

Bibliography

McAdams—Heat Transmission, 1933.

Fage—British Air Ministry; Reports and Memoranda, No. 1370, 1931, and No. 1179, 1929.

Discussion

Further Analysis Made of the Paper's Equations

—Benjamin Pinkel
Langley Field, Va.

THE equation given in the paper,

$$t_w = t_a + C \cdot \frac{\mu^x}{k} \cdot \frac{1}{(\rho V)^x} \qquad (1)$$

holds for a surface that is cooled by convection only, as the last term is the reciprocal of the surface heat-transfer coefficient for pure convection. The wall of a finned cylinder, however, is cooled by conduction through the fins and convection from the surface of the fins. The equation that applies for this case is

$$t_w = t_a + \frac{H}{U} \qquad (2)$$

where H is the heat dissipated per square inch of cylinder wall per second and U is the heat transferred per second per degree difference in temperature between the cylinder wall and the air per square inch of wall area. The factor U is given[a] by the equation

$$U = \frac{q}{p}\left[\frac{2}{\sqrt{\frac{2q}{kt}}} \cdot \frac{R_a}{R_b} \cdot \tanh W'\sqrt{\frac{2q}{kt}} + S\right] \qquad (3)$$

where

p = pitch of fins
W' = width of fin
t = thickness of fin
S = space between fins
k = thermal conductivity of fins
q = surface heat-transfer coefficient for convection of heat from surface of fins
R_a = average fin radius
R_b = radius to base of fin, and

$$q = \frac{C_1 k_a}{\mu^x} \cdot (\rho V)^x \qquad (4)$$

in which $x = 0.8$ for turbulent boundary layers, which applies for the usual cooling conditions encountered in practice. From these equations it can be seen that when the equation for the cylinder-wall temperature is written in the form

$$t_w = t_a + \frac{C_2}{(\rho V)^M} \qquad (5)$$

the value of M is less than 0.8 and must be a function of the dimensions of the fins and of the mass flow ρV of the cooling air. Values of M, calculated by means of the above equations for a typical fin design and for a range of mass flows corresponding to that obtained in practice, lie between 0.5 and 0.4.

The exponent of 0.8 given in the N.A.C.A. publications, which seems to have the author worried, applies for the variation of q with mass flow, and from the above considerations it is evident that there is no reason why this value should check the values obtained for the variation of cylinder-wall temperature with mass flow.

With reference to the author's explanation for the variation in the exponent based on a consideration of the boundary layer, I wish to state that the boundary layer for finned cylinders becomes turbulent near the front of the cylinder for the usual range of cooling conditions, and for all practical purposes the boundary layer can be considered as turbulent for the entire cylinder. It is extremely doubtful whether there is sufficient shift in the position of the transition point as a result of the addition of baffles to the cylinder to have more than a minor effect on the value of the exponent associated with q. Tests conducted at the N.A.C.A. on baffled and unbaffled cylinders give the same value for this exponent in both cases[b].

The value of from 5 to 7 per cent given in the paper as the effect of viscosity and conductivity of the air on the cylinder-wall temperature for 100-deg. fahr. variation in cooling-air temperature appears high. The value should be closer to 2 per cent.

The equation given in the paper as a second approximation corrects for the variation of viscosity and thermal conductivity resulting from temperature change. The coefficient 0.05 in this equation should be 0.02. The correction given by this equation would at most amount to less than 8 deg. fahr., and, in view of the uncertainty in the value of the exponent in the equation given as the first approximation, could very well be neglected.

[a] See N.A.C.A. 1934 Technical Report No. 488.
[b] See N.A.C.A. Technical Report No. 511.

Fuel Volatility and Cold Starting

WITH present fuels, cold-starting problems have become largely a matter of engine friction, liquid distribution and accumulation, and the providing of the proper fuel-air ratios during the cranking and initial running periods.

But, at present, engine friction is of primary importance, and the ability of the engine to start and run at zero temperature is more often determined by engine friction than by variations in volatility between various types of fuels. If the engine friction is higher than the horsepower the engine is capable of developing during the period of initial firing, the engine cannot run without the aid of the starting motor until the friction has been reduced to where the developed horsepower is greater than the frictional horsepower, regardless of the grades of gasoline being used.

The oil industry and the car manufacturers have acquainted the public with the importance of engine friction as related to cold starting and of the use of suitable oils for climatic temperature conditions. If the public will use the proper oils to meet these conditions, very satisfactory starting results can be obtained with present conventional or average fuels, even in extremely low temperatures.

The cold-starting problem is one of supplying a fuel-air ratio during cranking and initial running that will allow the engine to continue to fire without excessive accumulation until the friction has been reduced sufficiently so that the engine can run under its own power.

Excerpt from the paper "What Price Dynamite?" presented at the Semi-Annual Meeting of the Society, White Sulphur Springs, West Va., June 20, 1935, by C. H. Jorgensen, Delco-Remy Corp.

An Analysis of Critical Stresses in Aircraft-Engine Parts

By C. Fayette Taylor

Professor of Automotive Engineering, Massachusetts Institute of Technology

ALTHOUGH it has been customary for machine designers to determine the size of stressed parts by computation based on the applied loads and on the elementary formulas of applied mechanics, and then to use a generous "factor of safety" in doubtful cases, these methods are quite inadequate in the case of high-speed-engine parts.

For engine parts which are under fatigue loading and always have regions of stress concentration, the critical stresses are of a local character.

Detailed consideration is given to local stresses, and a brief review of the endurance properties of the more important aircraft-engine materials is given.

These materials include steel, aluminum alloys, magnesium alloys, and bronzes.

Design procedure and empirical methods of stress determination are cited.

In conclusion it is stated that even when the stress determination has been determined and suitable design changes made to distribute the stresses as evenly as possible, exhaustive testing under service conditions is still necessary.

IT has long been customary for designers of machinery to determine the size of stressed parts by computations based on the applied loads and on the elementary formulas of applied mechanics. In cases of doubt, a generous "factor of safety" has been used. Such methods may be sufficiently valid for structures under static loading, especially where parts are of uniform cross-section and of considerable length, as in the case of tension and compression members in bridges, roof trusses and airplane structures. That these methods are quite inadequate in the case of high-speed-engine parts is evidenced by frequent failure, during the development stage, of parts where the "factor of safety" has apparently been more than generous. A careful fundamental analysis indicates why this is to be expected.

In steadily stressed members, failure will not occur except from stresses above the elastic limit. This gives an opportunity for high local stresses to be relieved by plastic flow, before failure occurs. Thus, in statically loaded structures, if local stresses around rivet holes, changes of section and the like exceed the elastic limit, local flow can take place until such stresses are reduced, provided, of course, that the material is sufficiently ductile and that the average stress is not too high.

Practically all engine parts, however, are subject to rapidly fluctuating loads, and *failures, when they occur, are almost invariably of the fatigue type.* Experience shows that plastic

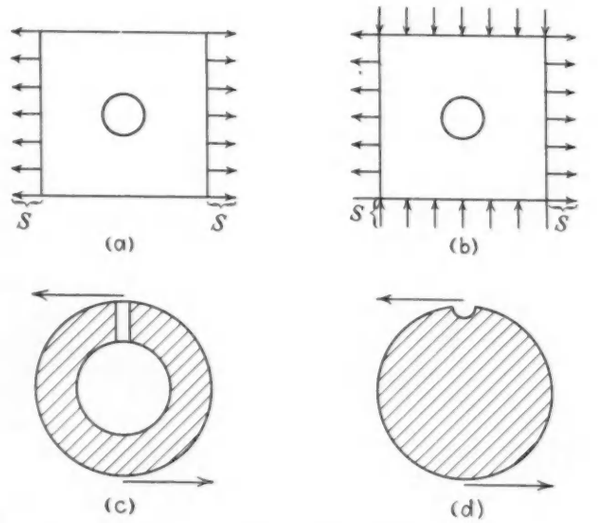


Fig. 1—Examples of Stress Concentration

[This paper was presented at the Regional Meeting of the Society, Hartford, Conn., April 26, 1935.

flow is a very unimportant factor under fatigue conditions. This is certainly to be expected where the maximum stresses are below the elastic limit of the material. But even under conditions where fatigue failure occurs at stresses above the elastic limit, it always takes place in regions of stress concentration. From this it must be evident that for engine parts —which are under fatigue loading and always have regions of stress concentration—*the critical stresses are of a local character.*

Local Stresses

The theoretical approach to the question of local stress is through the theory of elasticity[1], which assumes homogeneous material structure. While this assumption is far from true for most structural materials, the results obtained through it are qualitatively useful.

Fig. 1 shows several typical examples. It has been shown mathematically[1] that the highest local stress at the edge of a small hole in a large plate, Fig. 1*a*, is independent of the size of the hole and is equal to three times the uniform tensile or compressive stress, *S*, at the ends of the plate. When the hole is near the edge of the plate, the local stress is even greater. When a tensile—or compressive—load is applied on

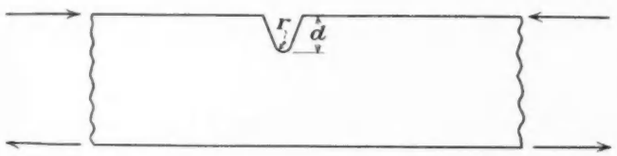


Fig. 2—Example of a Notched Beam

all four sides of the plate the maximum stress at the periphery of the hole is 2*S*, and when the plate is in pure shear, Fig. 1*b*, the maximum local tensile or compressive stress at the edge of the hole is four times the corresponding stress in the plate. A hollow shaft in torsion, with a radial oil-hole, Fig. 1*c*, is a practical example approaching the latter case. The weakening effect of such holes is, therefore, very serious.

Likewise, it has been shown that a small semi-circular groove in a shaft in torsion, Fig. 1*d*, gives a maximum stress in the groove equal to twice the maximum fiber stress in the same shaft without the groove. Rectangular, or gear-tooth shaped, splines or keyways lead to even greater concentrations of stress than does this semi-circular groove. It is interesting to note that the fatigue strength of splined shafts is likely to be materially less than that of smooth shafts of a diameter equal to the *minimum* diameter of the splines.

Notches and grooves in the surfaces of stressed parts also lead to high concentrations of stress. The intensity of the local stress depends on the depth of the notch and the radius of curvature, *r*, as in Fig. 2. This explains the marked effect of scratches, tool marks, pits, and other surface irregularities in reducing the fatigue strength of machinery parts[2].

[1] See "Theory of Elasticity," by A. E. H. Love; University Press, 1927. See also "Theory of Elasticity," by S. Timoshenko; McGraw-Hill Book Co., 1934.

[2] See "The Fatigue of Metals," by H. F. Moore and J. B. Kommers; McGraw-Hill Book Co., 1927. See also "Resistance of Metals to Repeated Static and Impact Stresses," by R. R. Moore; *Proceedings of the American Society for Testing Materials*, vol. 24, part 2, 1924. See also "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes; N.A.C.A. Technical Memorandum No. 743, April, 1934. See also "Influence of Chemically and Mechanically Formed Notches on the Fatigue of Metals," by D. J. McAdam, Jr., and R. W. Clyne; National Bureau of Standards Research Paper RP-725, 1934.

[3] See "Theory of Elasticity," by S. Timoshenko; McGraw-Hill Book Co., 1934.

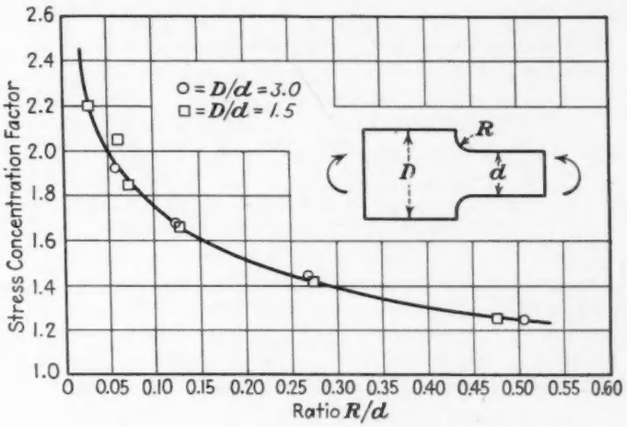


Fig. 3—Stress Concentration at Fillets in Pure Bending

Taken from "Theory of Elasticity," by S. Timoshenko. The Factor equals the Ratio.

$$\frac{\text{Maximum Stress in Fillet}}{\text{Maximum Stress in Section } d}$$

Fig. 3 shows stress concentrations at a simple change in section, as a function of the size of the fillets. While the values of stress concentrations at such points vary with the loading, relative cross-sections, and the like, the beneficial effect of large fillets in such places is quite evident. In this connection, it is important to remember that sharp changes in section are *unavoidable* in engine parts; in fact, they are the rule rather than the exception. An excellent illustration is the crankshaft.

Short Beams.—The methods of elementary applied mechanics make no allowance for local stresses near the points of support and the points of load application of members in bending. These effects usually lead to local stresses much higher than those at other points on the beam, and are, therefore, decisive in designs subject to fatigue loading. The maximum local stresses in a very short beam are likely to be other than simple tension and compression along its edges. Examples in point are piston-pins and hinge-pins, which are so short that the maximum stresses could not be predicted theoretically, even if the applied loads were accurately known. In the case of short rocker-arms, there may be no justification for the I-sections quite often used.

Torsion.—The theory of torsional stresses in non-circular shapes[3] does not take into account the complex effects which occur near the points of load application. Since most engine parts in torsion, for example, crankpins and crankarms, are very short compared to their thickness, the maximum stresses in them are largely determined by the end effects, and cannot be predicted with accuracy even by the most advanced mathematical methods.

Rollers and Balls.—On account of the symmetry of spheres and cylinders, the stresses in rollers or balls in contact with various simple surfaces can be predicted with a fair degree of accuracy[3]. The mathematics involved, however, are somewhat complex, and the results are of use chiefly in the design of ball and roller bearings, which is usually the province of specialists in this field. Useful applications of the theory might also be made in the case of rollers on cams and valve stems.

Correlation of Elastic Theory with Test Results.—Fortunately, with actual materials the effect of local stresses is not usually as serious as the elastic theory would indicate. The

Table 1—Effect of Stress Concentration on Endurance Properties of Several Engine Materials

Material	Endurance Limit: Smooth and Polished, Lb. Per Sq. In.	Endurance Limit: Notched or with Hole, Lb. Per Sq. In.		Ratio: Theoretical	Ratio: Actual	Authority
S.A.E. 1050 Steel	57,000	24,000	Notch in Bending	0.22	0.42	R. R. Moore [a]
Extruded Aluminum Bronze	34,000	20,000	Notch in Bending	0.22	0.59	R. R. Moore [a]
Extruded Magnesium plus 4 per cent Aluminum	12,000	8,000	Notch in Bending	0.22	0.67	R. R. Moore [a]
Cast Aluminum Bronze	26,000	22,000	Notch in Bending	0.22	0.85	R. R. Moore [a]
0.52 Carbon Steel; Normalized	42,000	32,000	Radial Hole in Bending	0.33	0.76	H. F. Moore [b]
0.02 Carbon Steel	26,000	20,000	Radial Hole in Bending	0.33	0.77	H. F. Moore [b]
Cast Iron	.....	.....	Notch	0.33	0.87	H. F. Moore [c]
Cast Iron	.....	.....	Notch	0.26	1.00	H. F. Moore [c]
Cast Iron	.....	.....	Notch	0.26	0.92	H. F. Moore [c]

[a] See "Resistance of Metals to Repeated Static and Impact Stresses." by R. R. Moore; *Proceedings of the American Society for Testing Materials*, vol. 24, part 2, 1924.
[b] See "The Fatigue of Metals," by H. F. Moore and J. B. Kommers; McGraw-Hill Book Co., 1927.
[c] See "Fatigue Tests of Cast Iron," by H. F. Moore and S. W. Lyon; *Transactions of the American Foundrymen's Association*, vol. 35, p. 423.

[4] See "The Fatigue of Metals," by H. F. Moore and J. B. Kommers; McGraw-Hill Book Co., 1927. See also "Endurance Properties of Non-Ferrous Metals," by D. J. McAdam, Jr.; *Transactions of the American Institute of Mining and Metallurgical Engineers*, 1925, p. 66.
[5] See "The Fatigue of Metals," by H. F. Moore and J. B. Kommers; McGraw-Hill Book Co., 1927. See also "Resistance of Metals to Repeated Static and Impact Stresses," by R. R. Moore; *Proceedings of the American Society for Testing Materials*, vol. 24, part 2, 1924. See also "Endurance Properties of Steel; Their Relation to Other Physical Properties," by D. J. McAdam, Jr.; *Proceedings of the American Society for Testing Materials*, 1923, vol. 23, p. 56.

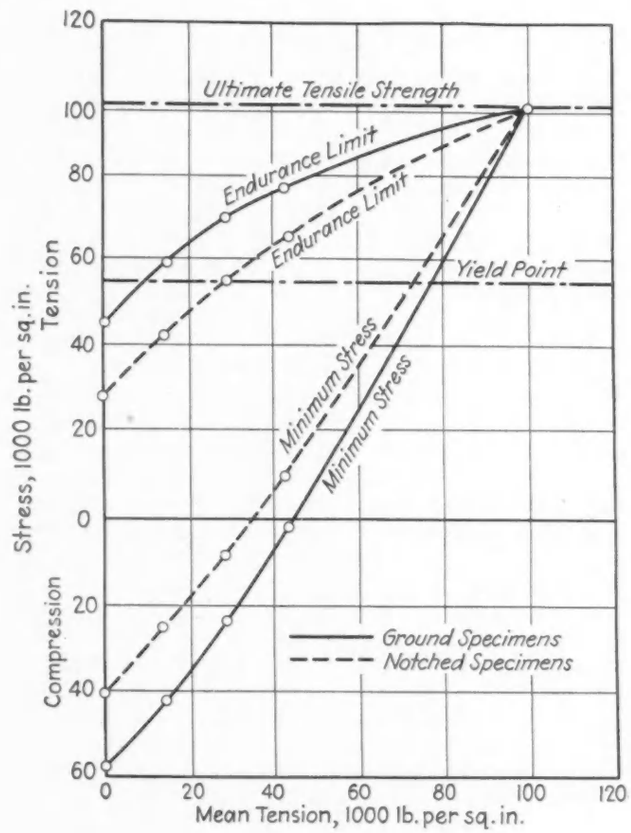


Fig. 4—Effect of Range of Stress on Endurance Limit
Taken from "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes.

extent of the departure from theory varies with the kind of material used. A brief review of the endurance properties of the more important aircraft-engine materials will, therefore, be of interest.

Endurance Limit

Most data with regard to the behavior of materials under fatigue loading involve the use of the property known as the "endurance limit". This property is broadly defined as the maximum of the fluctuating stress which a material will withstand indefinitely without failure. It is not a fixed quantity, but varies with (*a*) the range of stress variation, (*b*) the type of stress, and (*c*) the shape and finish of the specimen. Most of the available data on endurance limit[4] come from tests on smooth rotating-beam specimens, where the stress at any point varies harmonically from a maximum in tension to an equal maximum in compression. Many non-ferrous materials show no definite endurance limit, but fail under a stress which becomes progressively lower as the number of cycles is increased. In this case, the "endurance limit" is based on an arbitrary number of stress cycles.

Since endurance properties vary with test conditions, and since test conditions seldom, if ever, exactly represent operating conditions, it is apparent in this case again that the available data must be considered as applying to the engine structure largely in a qualitative sense.

Influence of Stress-Range on Endurance Limit.—Since most engine parts are not subject to completely reversed loading, it is of especial interest to investigate the endurance limit where the stress consists of an alternating stress superimposed upon a steady stress. It is obvious that in the limit, where the alternating stress approaches zero, the stress for failure will approach the ultimate tensile strength. Fig. 4 shows the relationship between stress-range and endurance limit for one type of steel. Experience shows that this relationship varies with the material in question, and with the type of stress. Indications are, for steel, at least, that the curves continue to the left with the same slope, allowing still greater ranges of stress on the compression side.

Influence of Type of Stress on Endurance Limit.—Figs. 5 and 6 show endurance limits for steel specimens under bending and torsional reversal stresses. The difference in value for the two types of stress is apparent. Considerable information is also available for steel under repeated impact stresses[5],

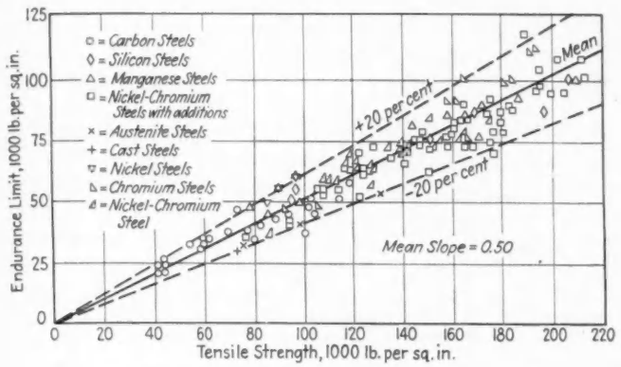


Fig. 5—Endurance Limit (Reversed Bending) versus Tensile Strength

Taken from "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes.

but the data for non-ferrous metals for stresses other than reversed bending are apparently quite meager. In this connection, it is well to remember that most stresses in engine parts are of a combined nature, and the endurance limit under such conditions may be different from that under a simple stress. Experimental data in this field are extremely few[6].

Influence of Shape and Finish.—Figs. 7 and 8 and Table 1 give some data on the influence of shape and finish on the rotating-beam endurance-limit of a number of materials. The following trends, shown by these data, are of especial interest.

(1) The effect of notches and surface irregularities is always less than the elastic theory predicts. This is, apparently, due to the fact that no material is perfectly homogeneous, and therefore local stresses are bound to be present, even with uniform sections smoothly finished. There is also some evidence that small amounts of plastic flow occur even under fatigue conditions.

(2) The effect of irregularities increases in intensity as the tensile strength of the material increases.

(3) Corrosion may be an important cause of serious surface irregularities.

(4) In general, while the endurance limit of cast materials is lower than that of forged rolled, or extruded materials, the cast materials are much less affected by irregularities of shape or of surface; see Table 1. This is probably because cast materials contain irregularities which lead to high stress concentration quite independent of shape or of surface finish.

Endurance Properties of Individual Materials

In addition to the general trends already noted, there are certain endurance properties characteristic of individual materials, which are worthy of attention.

Steel.—Endurance Limit versus Tensile Strength and Hardness.—Of especial interest is the fact that the endurance limit of steel, with completely reversed stress, increases with increasing tensile strength (hardness), as shown in Figs. 5 and 6. For parts where the stresses are largely alternating in character, such as crankshafts and connecting-rods, it is of interest to inquire whether or not it would be desirable to increase the hardness above present practice (275 to 325 Brinell). The answer to this question is at least partially found in Figs. 9 and 10, which show that the endurance limit of notched or rough specimens does not increase very rapidly at high hardness values. It is probable that the average engine part, with its irregularities both of section and of surface finish, behaves more like a rough or notched specimen than like a smooth specimen.

Another limit on hardness is the difficulty of heat-treating parts of complicated shape and large cross-section to high hardness without grave risk of internal stresses which would impair rather than improve fatigue resistance. The specimens used in endurance testing are usually so small and so uniform in section that there is little danger of such defects. Even with smooth test-specimens, however, H. F. Moore[7] gives data to show that the curve of endurance limit versus hardness eventually reaches a peak.

In this connection, it is interesting to note the beneficial effect of case-hardening on the endurance limit of a low-carbon steel in bending; see Fig. 11. By this means, hardness of the most highly stressed portion—the surface—is obtained without danger of internal stresses. As might be expected, failure of case-hardened parts in fatigue often starts just below the hardened surface, where the maximum ratio of stress to endurance limit may occur. There are also some data to show that nitrogen hardening has a beneficial effect on endurance properties.

Ductility.—In view of the popular belief that ductility is an essential property of machinery parts, it is interesting to note its lack of definite relationship to endurance limit[7]. One is forced to conclude that, under conditions of rapidly alternating stress, ductility in itself is not a useful property. Under conditions where occasional heavy overloads are likely, as in the running gear of road vehicles, ductility, that is, the ability to bend without breaking, is probably an important quality.

Effect of Yield-Point

It is believed that yield-point, under certain circumstances, may affect endurance properties so as to reverse the ordinary trend of increasing endurance limit with increasing tensile strength. For example, experience has shown that screw fastenings in engines are likely to fail if made too hard. A possible explanation of this may be deduced from Fig. 12. It is assumed that a bolt is tightened so that the average stress

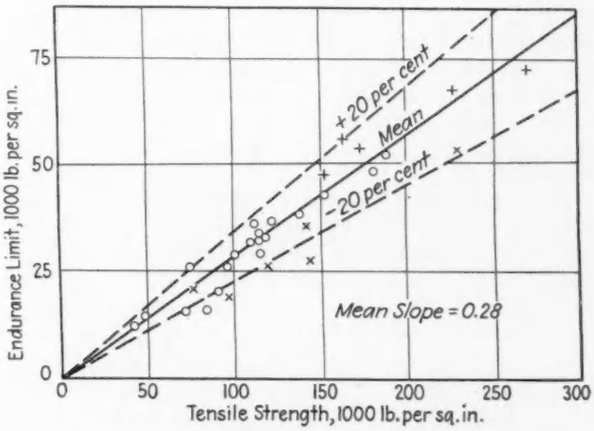


Fig. 6—Torsional Endurance Limit versus Tensile Strength of Steels

Taken from "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes.

[6] See "Fatigue of Steel under Combined Bending and Torsion," by A. Ono; Mem. Coll. Eng. Kyushu Imperial University, Vol. 2, No. 2, 1921. See also "On the Fatigue Resistance of Mild Steel under Various Conditions of Stress Distribution," by T. E. Stanton and R. C. Batson; *Engineering* (London), part 2, 1916 and part 1, 1917.

[7] See "The Fatigue of Metals," by H. F. Moore and J. B. Kommers; McGraw-Hill Book Co., 1927.

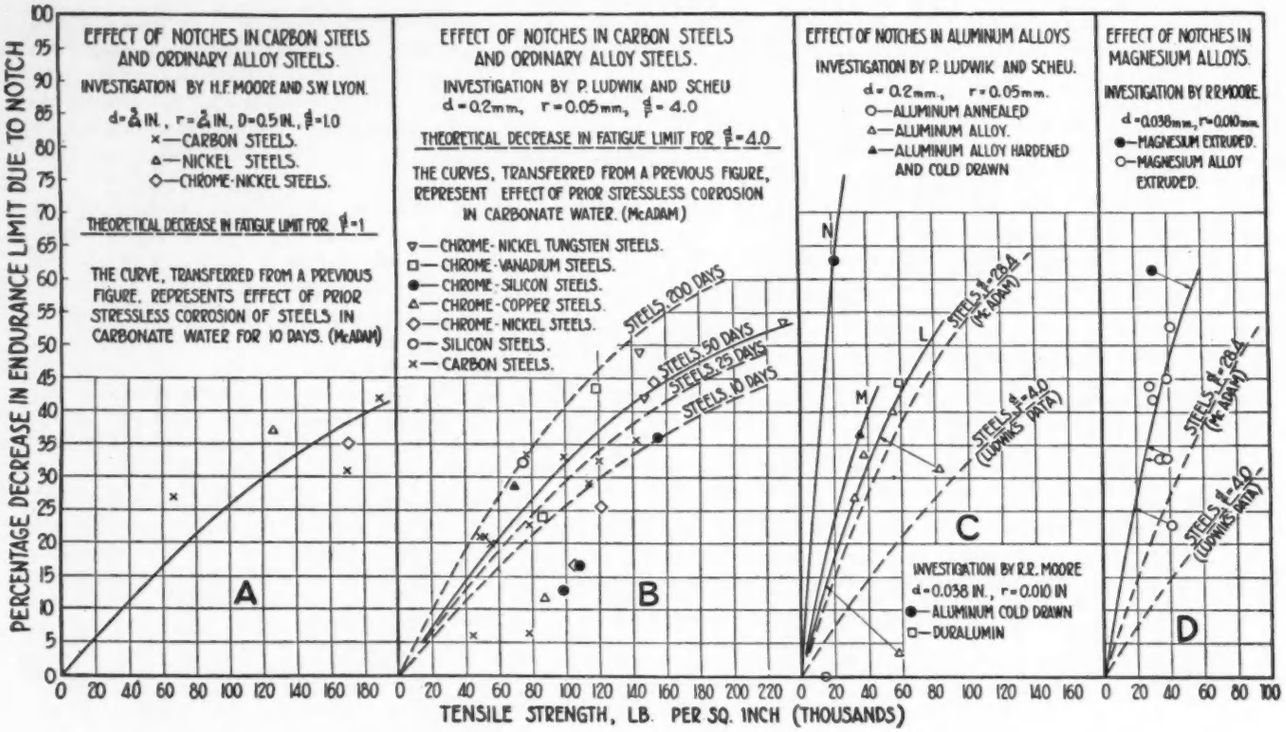

EFFECT OF NOTCHES IN CARBON STEELS AND ORDINARY ALLOY STEELS.
INVESTIGATION BY H.F. MOORE AND S.W. LYON.
d = 1/8 IN., r = 1/8 IN., D = 0.5 IN., d/r = 1.0
×—CARBON STEELS.
△—NICKEL STEELS.
◇—CHROME-NICKEL STEELS.
THEORETICAL DECREASE IN FATIGUE LIMIT FOR d/r = 1
THE CURVE, TRANSFERRED FROM A PREVIOUS FIGURE, REPRESENTS EFFECT OF PRIOR STRESSLESS CORROSION OF STEELS IN CARBONATE WATER FOR 10 DAYS. (McADAM)
A
EFFECT OF NOTCHES IN CARBON STEELS AND ORDINARY ALLOY STEELS.
INVESTIGATION BY P. LUDWIK AND SCHEU
d = 0.2mm, r = 0.05mm, d/r = 4.0
THEORETICAL DECREASE IN FATIGUE LIMIT FOR d/r = 4.0
THE CURVES, TRANSFERRED FROM A PREVIOUS FIGURE, REPRESENT EFFECT OF PRIOR STRESSLESS CORROSION IN CARBONATE WATER. (McADAM)
▽— CHROME-NICKEL TUNGSTEN STEELS.
□— CHROME-VANADIUM STEELS.
●— CHROME-SILICON STEELS.
△— CHROME-COPPER STEELS.
◇— CHROME-NICKEL STEELS.
○— SILICON STEELS.
×— CARBON STEELS.
STEELS, 200 DAYS
STEELS, 50 DAYS
STEELS, 25 DAYS
STEELS, 10 DAYS
B
EFFECT OF NOTCHES IN ALUMINUM ALLOYS
INVESTIGATION BY P. LUDWIK AND SCHEU.
d = 0.2mm., r = 0.05mm.
○—ALUMINUM ANNEALED
△—ALUMINUM ALLOY.
▲—ALUMINUM ALLOY HARDENED AND COLD DRAWN
N
L
M
STEELS d/r = 2.8 (McADAM)
STEELS d/r = 4.0 (LUDWIK'S DATA)
C
INVESTIGATION BY R.R. MOORE
d = 0.038 IN., r = 0.010 IN
●—ALUMINUM COLD DRAWN
□—DURALUMIN
EFFECT OF NOTCHES IN MAGNESIUM ALLOYS.
INVESTIGATION BY R.R.MOORE.
d = 0.038mm., r = 0.010mm.
●—MAGNESIUM EXTRUDED.
○—MAGNESIUM ALLOY EXTRUDED.
STEELS d/r = 2.8 (McADAM)
STEELS d/r = 4.0 (LUDWIK'S DATA)
D
PERCENTAGE DECREASE IN ENDURANCE LIMIT DUE TO NOTCH
TENSILE STRENGTH, LB. PER SQ. INCH (THOUSANDS)

Fig. 7—Relation between Tensile Strength and Percentage Damage Due to Notches in Various Metals and Alloys

Taken from "Influence of Chemically and Mechanically Formed Notches on Fatigue of Metals," by D. J. McAdam, Jr., and R. W. Clyne.

is 50,000 lb. per sq. in. with an alternating stress of ± 10,000 lb. per sq. in. It is further assumed that, if no plastic flow takes place, the design of the bolt, together with eccentricity of load, and the like, causes a maximum local stress four times the average stress. Curve (*a*) is plotted on the basis of average data for the yield-point of steel versus tensile strength, and Curve (*b*) for the endurance limit with a stress range of 2/5 the average stress; see Fig. 4.

If it is assumed that the maximum local stress cannot exceed the yield-point, the shaded area shows the stress and stress range in the bolt for various values of the hardness (ultimate tensile strength). It is evident that the maximum factor of safety with regard to the endurance limit occurs at a hardness of 185 Brinell, or else above 480 Brinell. The latter hardness is impractical on account of the danger of internal stresses or cracks. Between 350 and 480 or below 130 Brinell, failure due to fatigue will occur. This may explain the prevalent idea that ductility is an important factor, for with steel at least, yield-point goes down with increasing ductility. This same type of analysis would apply to other structural members, where a similar set of conditions exist. The necessary conditions are a high stress concentration, and a crossing of the curves of yield-point and endurance limit. In the case of steel, the latter condition occurs only when the stress range is low.

The *impact strength* of steel, that is, the work required to fracture a given specimen under very rapid application of load, apparently bears no direct relation to endurance strength[8]. With a given material at a given hardness, however, variation in impact strength probably indicates variation in the uniformity of the material structure—due to in-

[8] See "The Fatigue of Metals," by H. F. Moore and J. B. Kommers; McGraw-Hill Book Co., 1927.

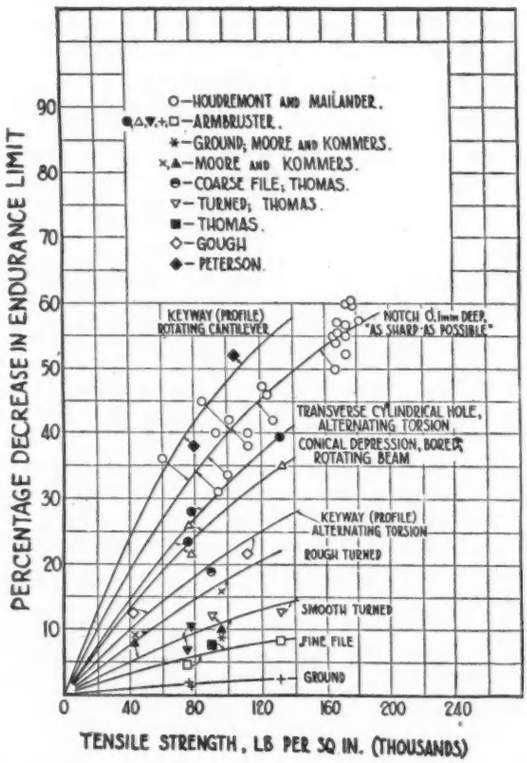


Fig. 8—Effect of Notches and of Surface Finish on Endurance Limit of Steel Specimens

Taken from "Influence of Chemically and Mechanically Formed Notches on Fatigue of Metals," by D. J. McAdam, Jr., and R. W. Clyne.

clusions, cracks, and imperfections in general—and under these circumstances should correlate with fatigue strength. No attempt at such correlation has as yet come to the attention of the author.

Alloy versus Carbon Steel.—Figs. 5 and 6 show that, within the range of tensile strength where they are used, the carbon steels appear to have as good endurance properties as the alloy steels. As a rule, carbon steels for use in structural parts are not heat-treated to above about 120,000 lb. per sq. in. This is, apparently, because the low drawing-temperatures required are likely to introduce internal strains or incipient cracks. From the endurance point of view, the advantage of alloy steels appears to be the possibility of obtaining, by heat-treatment, greater tensile strength, and hence greater endurance strength than is feasible with plain carbon steels.

Effect of Temperature.—See Fig. 13. Apparently the endurance limit of steel is not adversely affected by increase in temperature, within the range generally encountered in internal-combustion-engine parts—up to 500 deg. fahr. This is not true of exhaust valves, however, which may run at much higher temperatures—up to 1400 deg. fahr. Special alloys are therefore necessary for these parts.

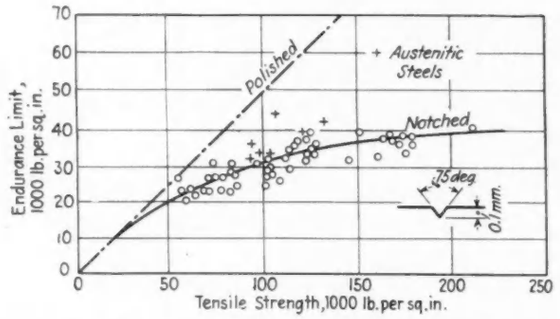


Fig. 9—Notch Sensitiveness and Tensile Strength of Steel According to Houdremont and Mailander

Endurance limit (reversed bending) versus tensile strength. Taken from "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes.

Endurance Strength of Aluminum Alloys

Fig. 14 shows endurance limit versus ultimate tensile strength for a number of aluminum alloys. For these materials the true endurance limit is not well defined, and is usually taken as the stress which will cause failure after 10^7 cycles of stress alternation. The relatively low ratio of endurance limit to ultimate strength is notable (0.35 for aluminum, as compared with 0.50 for steel). Since the weight of aluminum is about one-third that of steel, forged aluminum of 60,000 lb. per sq. in. ultimate tensile strength has an endurance-limit-to-weight ratio about equal to that of steel heat-treated to 120,000 lb. per sq. in. ultimate tensile strength. On the other hand, for sections of equal weight, a duralumin beam could be made three times as deep as the corresponding steel beam.

Taking the ratio of the endurance limits as 0.35, and remembering that bending stress decreases as the depth squared, the aluminum section has an advantage over the steel section in the ratio $0.35 \times (3)^2 = 3.15$. For cast aluminum, taking the endurance limit as 10,000 lb. per sq. in., there is still an advantage in the ratio 1.5. Fig. 7 shows the serious effect of notches and other surface irregularities on the endurance properties of forged aluminum (duralumin). This justifies

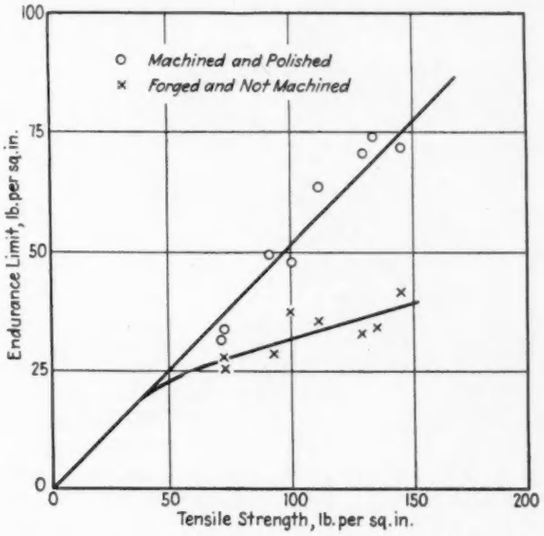


Fig. 10—Effect of Surface Decarbonization on the Endurance Limit of Forged Test-Specimens in Reversed Bending

Taken from "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes.

the practice of polishing such parts as aluminum propeller-blades for aircraft. While few data are available, indications are that the cast alloys are much less sensitive to notches and surface irregularities than are the forged or rolled alloys.

The actual value of the endurance limit of the cast material, however, is generally less than that of the forged or rolled material, even when both are notched. Since the tensile strength of aluminum falls off rapidly with increasing temperatures, it is probable that the endurance limit does also, even within the range encountered in internal-combustion engines. This factor must be taken into account when aluminum is used for cylinder heads, pistons, and the like. Experimental data are needed to show the extent of this effect.

Endurance Properties of Magnesium Alloys.—Fig. 15 shows the endurance limit of some magnesium alloys. This material loses strength at high temperatures even more than aluminum and it is probable that the endurance limit is correspondingly impaired. More data are needed for this mate-

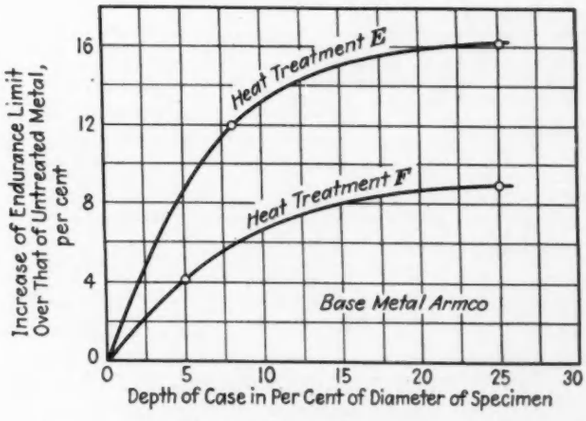

Heat Treatment E
Heat Treatment F
Base Metal Armco
Increase of Endurance Limit Over That of Untreated Metal, per cent
Depth of Case in Per Cent of Diameter of Specimen

Fig. 11—Effect of Case-Hardening on the Endurance Limit of Low-Carbon Steel

Taken from "The Fatigue of Metals," by H. F. Moore and J. B. Kommers.

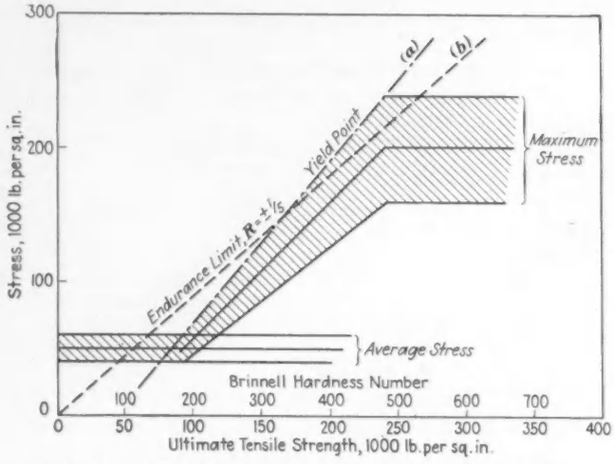


Fig. 12—Chart Showing the Effect of Yield-Point on Safety Factor, with Stress Concentration

rial, especially with regard to the effects of stress range, type of stress and temperature effects. Some data with respect to its notch sensitivity are available[9].

Endurance Properties of Bronzes.—Considerable information is available on the endurance properties of the brasses, bronzes, and the like[10], but the use of these materials for structural purposes is very limited in aircraft engines. None of the data are reproduced here. In general, these materials show a progressive falling off of endurance properties as the number of cycles increases, and the endurance limit must, therefore, be taken at an arbitrary number of stress reversals. Castings are, again, less sensitive to surface defects and notches, than the forged and rolled material; see Table 1.

Design Procedure

It must be apparent, from the foregoing, that it is futile to base the dimensions of most engine parts on any simple mathematical procedure. The large number of variables involved, and the lack of complete knowledge as to their effects, preclude precise theoretical treatment.

The first difficulty encountered is that of determining the amount and distribution of the applied loads. In the case of engine parts, many of the applied loads can be computed with a fair degree of accuracy, but the distribution of these loads at the points of application is usually indeterminate. Even when the loads and their distribution are known with considerable accuracy, the prediction of stresses in such irregular shapes as are encountered in an engine is generally outside the bounds of quantitative theoretical treatment.

Assuming, however, that stresses were completely known, there would still remain the difficulty of predicting how a given material would behave, for our knowledge of the endurance properties of materials is largely confined to tests on simple forms, over limited ranges of load variation, and with simple types of stress. Even our knowledge of the static properties of materials under complex stresses is very limited.

These difficulties account for the fact that designers have depended, and still depend, on the accumulated experience represented by designs already in successful operation. Where innovations are attempted, they are tested in the hard school of actual engine operation. The quality of a new design thus depends chiefly upon the intelligence with which previous experience has been applied, and on the thoroughness with which new features have been tested. The former process is greatly assisted by careful attention to questions of similarity[11], and by logical assumptions as to the relationship of dimensions to bore, stroke, speed, and the like. For example, for equal stresses in similar parts, fillet radii should be proportional to the other dimensions. This principle is often neglected when small engines are "scaled-up" to larger sizes, and is, together with cooling problems, largely responsible for the prevalent view that "scaling-up" is difficult.

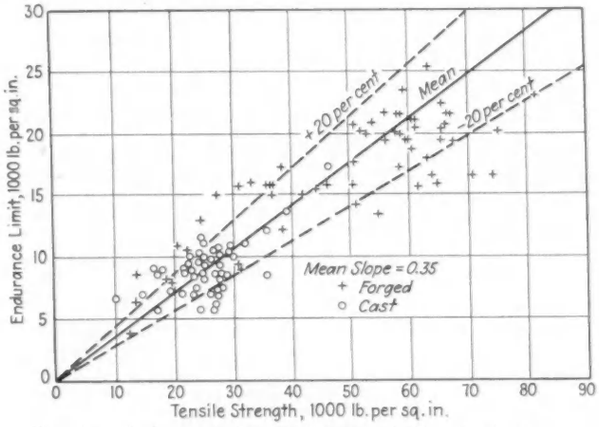


Fig. 14—Endurance Limit (Reversed Bending) versus Tensile Strength of Aluminum Alloys

Taken from "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes.

Empirical Methods of Stress Determination

Where economy of material is important, experimental investigation of the stress distribution in engine parts may be very helpful in arriving at a satisfactory design. Direct measurements on actual engine parts yield, naturally, the most reliable results. Most of the methods developed to date are not applicable to the engine in actual operation, and it is usually necessary to set the part in a special mounting and to apply loads based on calculations of the working loads. This, of course, introduces some error, though in many cases not a serious one. Some sort of strain gage with a very short gage-length is necessary, and one of the chief difficulties is properly to attach the gage points in restricted areas such as crankshaft fillets.

To avoid the necessity for placing strain gages in all pos-

(Continued on page 421)

[9] See "Resistance of Metals to Repeated Static and Impact Stresses," by R. R. Moore; *Proceedings of the American Society for Testing Materials*, vol. 24, part 2, 1924.

[10] See "Endurance Properties of Non-Ferrous Metals," by D. J. McAdam, Jr.; *Transactions of the American Institute of Mining and Metallurgical Engineers*, 1925, p. 66.

[11] See "Design Limitations of Aircraft Engines," by E. S. Taylor; *Aero Digest*, January, 1935.

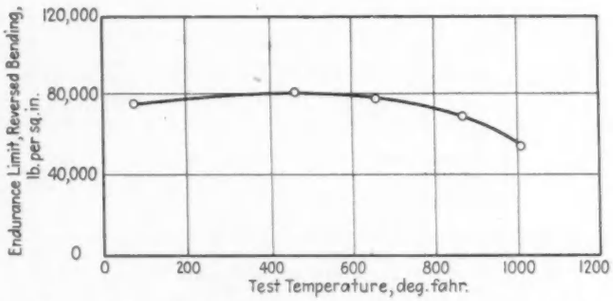


Fig. 13—Effect of Temperature on Endurance Limit of S.A.E. 2340 Steel

Taken from "The Fatigue of Metals," by H. F. Moore and J. B. Kommers.

Design and Maintenance Problems on Heavy-Duty Brakes

By Norman Leeds, Jr.
Raybestos-Manhattan, Inc.

THIS paper sets forth some of the many problems connected with the design and maintenance of heavy-duty brakes that urgently require solution.

Satisfactory brakes, on the heavier vehicles at least, should include the following features:

(1) Brakes should be on all wheels, utilizing the entire weight of the vehicle.

(2) They should be of internal construction with hinged shoes of some type.

(3) Power of some sort should be used to obtain the pressures necessary to stop the vehicle with comfortable effort on the part of the operator.

(4) Cast-iron drums, which give the best results so far as known at present.

(5) The friction element should be some kind of so-called "fabricated" material, not so hard as the drum and in an easily replaceable form.

Detailed consideration of each of the foregoing five points is then presented, and a summary covering 10 desirable features for heavy-duty brakes is appended.

FEW will deny that many problems are connected with the design and maintenance of heavy-duty brakes that urgently require solution. The purpose of this paper is to set forth some of these problems as plainly as possible with, it is hoped, some indication of the direction from which the solutions may come.

We probably can take it for granted that experience in the last few years has definitely settled a number of questions in the design of such brakes and their application to heavy-duty vehicles. We will state these briefly and assume it agreed that satisfactory brakes, on the heavier vehicles at least, should include the following features:

(1) Brakes should be on all wheels, utilizing the entire weight of the vehicle

(2) They should be of internal construction with hinged shoes of some type

(3) Power of some sort should be used to obtain the pressures necessary to stop the vehicle with comfortable effort on the part of the driver

(4) Cast-iron drums give the best results so far as known

(5) The friction element should be some kind of so-called "fabricated" material, not so hard as the drum and in an easily replaceable form.

With these assumptions we can proceed to detailed consideration of each of the five points.

(1) *Weight of Vehicle Versus Total Area of Lining.*—Brakes are fundamentally power-absorption machines in which moving energy is transformed into heat by means of a friction surface. The ability of the brakes to absorb this energy without a destructive rise in temperature at the working surfaces depends on the effective braking area provided. In the case of most vehicles, the maximum speeds are practically a fixed quantity and so is the maximum possible deceleration. Therefore, the prime consideration is the total weight of the vehicle and the effective area of the friction material; or, as it is called, the weight-area ratio. This ratio, on heavy-duty vehicles, has varied very considerably in the past, not because designers did not understand the fundamental relations already stated but because they were not in agreement as to the amount of work each square inch of the friction material should be called upon to do to keep within reasonable limits of durability.

A compilation of some results at hand, gathered from various kinds of services, indicates that the wear is closely proportional to the weight-area ratio. For instance, for the same increment of wear in all cases, the record was as follows:

Weight-Area	*Mileage*
24	4,000
35	3,500
48	3,200
63	2,500
73	2,000
80	1,000

It is evident from this record that the only real way to get an increase of lining mileage is to make the weight-area ratios as small as possible.

On any type of hinged shoe, an arc of contact of more than 120 deg. is of no value from a brake-life standpoint; so, we at once arrive at the maximum frictional area that can reasonably be incorporated in the brake design for nearly any vehicle. With two shoes per wheel, the total arc of contact per wheel is 240 deg. With the frictional surface 18 in. in diameter and 7 in. wide, maximum, this means an area of about 265 sq. in. per wheel. It is, therefore, possible to put four times this brakage area on a vehicle with four-wheel brakes; but, on most buses and trucks, there is no object in putting the same area on the front as on the rear brakes because the rear brakes do 60 per cent of the total work, at

[This paper was presented at the Northern California Section Meeting, Oakland, Feb. 21, 1935.]

least. On this basis, the rear brakes could have a total area of 530 sq. in. and the front brakes would require only 353 sq. in. This is a total brake area of 883 sq. in. Therefore, a maximum of 883 sq. in. is about all that can be provided, with the present vehicle construction.

However, in a two-shoe enclosed-brake, both shoes do not produce the same amount of brake effort, one of them, sometimes called the primary shoe, doing about 70 per cent of the total work for the wheel. This does not refer to the servo type of brake, where one shoe is hinged to the other, but to those designs where the shoes are separately and independently hinged to the backing or support plate. Therefore, one-half of the area does 70 per cent of the total brake-work, which is equivalent to cutting down the total area to 630 sq. in.

If the vehicle weighs 30,000 lb., total, and has a maximum speed of 40 m.p.h. and can stop with a maximum deceleration of 15 ft. per sec. per sec., the work done by the friction surfaces in one stop at these maxima is 1,600,000 ft.-lb. The stop will require 3.9 sec. and the energy absorption will be nearly 750 hp. The horsepower absorption per square inch is $750/630 = 1.2$, nearly. These figures are not exaggerated in any way; a great many motorbuses are now made wherein the energy absorption per square inch of friction surface in one stop can be greater than 1.2 hp. When the energy absorption ranges around this figure, the rise in temperature at the friction surfaces is very rapid and can easily reach a high figure, probably over 1000 deg. fahr.

(2) *Internal-Brake-Shoe Design.* — Much can be written about the design of brake shoes, but we believe that experience to date, on a power-operated brake, indicates a preference for two simply and independently hinged shoes per wheel operated by a non-floating cam with the power application outside of the drum enclosure. The action of this type of shoe is now quite well known; so, we can perhaps predict the results fairly well from any given design. It is our idea that the following elements of design should be incorporated in a shoe for power brakes:

(1) The shoe should be of heavy construction, making it as rigid as possible

(2) Weight is a vital consideration, and aluminum-alloy shoes may be the solution if the clearances between lining and drum are worked out to prevent dragging when the drum cools off

(3) The lining should not be more than 120 deg. long

(4) The cam should be of the "rigid" type; that is, it does not follow up the shoe action

(5) It is believed that the anchor-pin hinge-points, the cam-shafts and possibly the cam-contact points, should be provided with anti-friction construction

(3) *Power Systems.*—It is not intended in this paper to go into the merits or demerits of any particular system, but we believe that power should be used on all installations over approximately 10,000 lb. of total vehicle-weight.

(4) *Drum Design.*—For many years low cost and light weight gave the preference to pressed-steel drums, but it is believed that experience has now indicated decisively that brake drums of a relatively heavy construction of cast iron are a necessity on all commercial vehicles. It is interesting to note that this trend in brake-drum material follows experience in clutch design where contact plates of cast iron have predominated for some time. However, cast-iron drums are not without their disadvantages and troubles, although their metallurgy and design have reached high points.

The problems in connection with the design of cast-iron drums can be stated briefly, separating them roughly into two categories: First, from the viewpoint of a satisfactory structure to meet the physical necessities of heat dissipation, strength, shape to resist distortion, and method of attachment; second, from a metallurgical standpoint to resist abrasion of wear, reduction of internal casting strains, and scoring.

The problems in the first category are outlined as follows:

(1) Although weight is a considerable factor, mass directly over the brake-lining path should be as great as possible. Temperature rise is very rapid at the contact surface, and a large reservoir for heat absorption is a necessity.

(2) The outside surface of the drum directly over the lining path should be left rough to accelerate the heat dissipation to the surrounding air. Ribs at this point, tending to increase the radiating surface, are a help.

(3) The temperature at the center line of the brake-lining path is undoubtedly greater than at any other point. This tends to cause greater expansion at that point. The transverse cross-section of the drum should be designed to resist this "bellying" as much as possible.

(4) Bell mounting also occurs due to heat and pressure. This consideration and that just mentioned indicate that the center of greatest mass should be between the open end of the drum and the center line of the brake-lining path.

(5) *Brake Lining Requirements.*—From the vehicle-makers' and the operators' viewpoints, it may be stated that there are two major requirements for brake lining. These are wear life and constancy of friction value during the wear life, under all conditions of operation. Under the first item it has been found that wear will be proportional to (*a*) the temperature of the working surface, and (*b*) the work done by the surface.

Dealing with the temperature factor which, at the higher values, can become a serious destructive agent, we can perhaps set down roughly the limitations of present-day brake-lining construction. Practically all friction materials in use at present have asbestos fiber as a base, bonded together by some form of organic material. Organic binders that can successfully withstand chemical or physical changes above approximately 400 deg. fahr. have not been found. Asbestos will commence to change its structure and fibrous nature above 800 deg. fahr. Therefore, we can consider two phases in the destructive progress of the lining due to temperature.

Above 400 deg. fahr., the character of the binder commences to change. This change is almost certainly one that weakens the binding properties. At 800 deg. fahr. the binder is practically destroyed and, above this temperature, the asbestos commences to lose its fibrous character. These changes are bound to affect resistance to wear and nearly always change the frictional value of the working surface.

The saving factor in the practical use of material of this nature is due to its slow heat-absorption and the fact that such destructive temperatures are not usually sustained long enough to affect more than a relatively thin working film.

All that we have already stated concerning changes in wear resistance due to temperature changes may also affect the frictional value of the working surface. Little is really known about the nature of the friction set up between the lining element and the drum surface, but we have found it helpful to divide the phenomenon into friction caused by, (*a*) the abrasion or tearing down of the drum and lining surface, and (*b*) friction caused by the "adhesion" of the organic binder in the lining. From this viewpoint it is interesting to note

that, of the foregoing causes, abrasion may have a stable value under temperature changes whereas the so-called "adhesion" value may change rapidly under variable temperatures.

In dealing with friction materials commercially satisfactory under the operating conditions of vehicles equipped with power brakes it is quickly learned that, when properly stabilized for frictional value, there is a decidedly narrow range of coefficients available. The best determination of these values places them somewhere between coefficients 0.25 and 0.40. In this range we believe abrasion of the surfaces is the dominant factor, with "adhesion" as the minor effect.

Without power brakes, however, linings with higher coefficients are generally needed. In such materials, the friction caused by the adhesion of the organic binder becomes more important. Such linings are relatively less stable, as to friction value, under variable temperatures; and it begins to become necessary to pick the lining to suit the job. It is becoming increasingly easy, fortunately, to predict positively what will give the desired results.

Summary

The foregoing considerations of heavy-duty automotive-brake design may be summarized as follows:

(1) For vehicles which at any time may be loaded to bring the total weight to about 10,000 lb., power of some kind should be used as the means of brake application

(2) Cast-iron drums of correct design are the most satisfactory today

(3) Internal brakes with independently hinged shoes seem to be in the greatest favor

(4) On account of the destructive effects of high temperatures, the weight-area ratio should be kept as low as possible. We would set a figure of not more than 30 lb. of total vehicle weight per square inch of lining area

(5) It is unprofitable to make the brake lining on any one shoe more than 120 deg. long

(6) The thickness of lining provided is entirely a matter of price. It is customary and probably more satisfactory to use bolts for fastening the lining to the shoes when the thickness is greater than ½ in.

(7) The coefficients available for a well-stabilized brake lining for use with heavy-duty vehicles is probably between 0.25 and 0.40

(8) Average surface temperatures of over 400 deg. fahr. for any great length of time increase wear very rapidly, but modern types of brake linings resist quite successfully temperatures between 400 and 800 deg. fahr.

(9) The abrasive value of a brake lining, as a stable friction factor, is important and should be kept in mind by the drum maker, the brake-lining manufacturer and the fleet operator

(10) Undoubtedly, weights and speeds will increase still further and, considering the limitations of present-day materials for lining and drums, there will be only a few courses open to the brake designer in his attempt to provide satisfactory brakes. Perhaps these could be listed as (*a*) more wheels on the vehicle; (*b*) auxiliary service-brakes at some other point than on the wheels; and (*c*) application of means for cooling the brake-drum surfaces.

[12] See "Das Dehnungslinienverfahren," by O. Dietrich and E. Lehr; *Zeitschrift des Vereines Deutscher Ingenieure*, October, 1932.

[13] See "Photo-Elasticity," by E. G. Coker and L. N. G. Filon; Cambridge University Press, 1931.

[14] See "Investigation of the Stresses and Strains in a Crankshaft by Means of a Rubber Model," by W. J. Larkin; *Thesis*, 1934, Library of the Massachusetts Institute of Technology.

An Analysis of Critical Stresses in Aircraft-Engine Parts

(Continued from page 418)

sible positions, Dietrich and Lehr[12] adopted the very clever expedient of coating the surface with a layer of brittle lacquer, which cracked under strain and revealed the location and direction of the important stresses. The use of this method on a certain apparently well-designed crankshaft revealed the points of maximum local stress and enabled this stress to be reduced over 50 per cent by simple design changes involving only the *removal* of a small amount of material.

Photo-Elastic Method[13].—Celluloid models are made of the section in question, and the stress distribution is explored by means of the refraction of polarized light passed through the stressed specimen. The method yields useful information on uniplanar stresses, but is not applicable to stresses in more than two dimensions. Torsional stresses are, therefore, difficult to explore by this method.

Special Models.—Useful qualitative, and perhaps even quantitative, results may be obtained by fracturing models made of brittle material. Since fatigue failure occurs without appreciable plastic deformation, such failure is similar

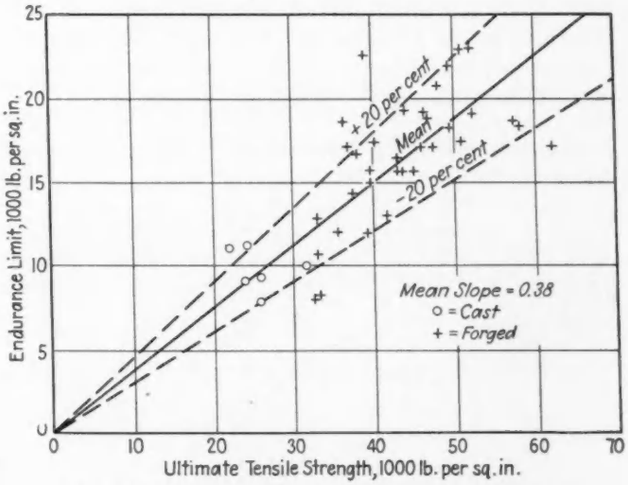


Fig. 15—Endurance Limit of Magnesium Alloys in Reversed Bending

Taken from "Fatigue Strength of Airplane and Engine Materials," by Kurt Matthaes.

to that of a very brittle material under steady load. Plaster of Paris and other similar materials have been used to investigate the probable location and character of the failure of irregular shapes by the use of models having quite the opposite characteristics. Rubber models, for example, give such large deflections under stress that deformations at points of stress concentration are relatively easy to measure[14].

In conclusion, it should be pointed out that even when the stress distribution has been determined, and suitable design changes made to distribute the stresses as evenly as possible, exhaustive testing under service conditions is still necessary. This is because of the incompleteness of our knowledge with regard to the nature and magnitude of the load cycles under actual operating conditions, and to the restricted amount of information available as to the endurance properties of materials under complicated conditions of stress and stress variation.

Application of Induction Heating in Automotive Production

By E. L. Bailey
Chrysler Corp.

INDUCTION heating is a process or method by which metal parts are heated by simply placing them in an alternating magnetic field.

The action is that of the transformer, whereby electrical energy is transferred or passed over to another isolated electric or secondary circuit by means of the magnetic field; thus, no physical attachments or electrical contacts are necessary to have electrical currents, which are dissipated as heat, flow in the parts to be processed.

The strength and frequency of the alternating magnetic field can be selected to produce any desired rate of heating and ultimate temperature.

A circuit can be set up to dry lacquer at 160 deg. fahr. on thin sheet-metal parts or to melt in record time immense steel ingots.

Induction heating is now commercially applied in automotive production to many processes, and these are specified.

The development of lower cost electrical apparatus suitable for induction heating has greatly stimulated its commercial use, and the field of application will rapidly expand as the many values of the process become better known.

THE idea of induction heating for industrial processes has long been most attractive to engineers and to production men alike. The thought of generating the heat required for a particular thermal process within the part being treated is most intriguing, carrying with it visions of high efficiency, rapid heating and many other secondary advantages.

The practical application of induction heating has for years been largely confined to melting processes, using both high and low frequency. However, a recent installation for heat treatment of steel in an inductively heated muffle was made with excellent success, while, in Cleveland, Ohio, crankshafts are being surface-hardened on the bearing surfaces only by induction heat, and now induction heating for paint drying is in very successful operation in one of our automobile plants.

[This paper was presented at the Production Meeting of the Society, Cleveland, Sept. 18, 1935.]

The fundamental principles briefly outlined show two sources of heat in a magnetic material when it is introduced into an alternating magnetic field; namely, hysteresis and eddy currents. The conditions of heating are expressed as follows:

$$W_h = 0.83 \times h \times f \times B^{1.6} \times 10^{-7} \text{ watts per cu. in.}$$
$$W_e = 40.64 \times t^2 \times f^2 \times B^2 \times 10^{-12} \text{ watts per cu. in.}$$

where

W_h = watts generated by hysteresis
W_e = watts generated by eddy currents
h = hysteresis constant for the material
f = frequency, cycles per sec.
B = flux density, lines per sq. in.
t = thickness of metal, in.

Factors 10^{-7} and 10^{-12} suggest at once very small values of the watts unless some of the other factors can be made large. Obviously B, the flux density, cannot be pushed beyond a certain limit; so, the only way to increase the watts loss is to increase the frequency. For example, let us check the heating at 60 cycles and 2000 cycles in a piece of No. 18 B. & S. 40-mil. ordinary sheet metal similar to that used in automobile bodies, placed in a field strength to give 90,000 lines per sq. in.

The hysteresis constant, h, of this steel, is 0.004.

	Watts per Cu. In.
$W_h = 0.83 \times 0.004 \times 60 \times (90{,}000)^{1.6} \times 10^{-7} =$	1.720
$W_e = 40.64 \times (0.04)^2 \times (60)^2 \times (90{,}000)^2 \times 10^{-12} =$	1.855
$W_h + W_e$ at 60 cycles =	3.570
$W_h = 0.83 \times 0.004 \times 2000 \times (90{,}000)^{1.6} \times 10^{-7} =$	57.000
$W_e = 40.64 \times (0.04)^2 \times (2000)^2 \times (90{,}000)^2 \times 10^{-12} =$	2,000.000
$W_h + W_e$ at 2000 cycles =	2,057.000

Thus, the heating effect for 60 cycles in this sheet is almost negligible; while the 2000 cycles will pour 2 kw. into 1 cu. in., raising its temperature to 1000 deg fahr. in 1¼ min.

The effective thickness of the section appears as a second-power function in this eddy-current-loss formula, meaning that a heavy section of two times the thickness of another section should absorb four times the energy. This would give a very rapid heating of the heavy sections, a condition

just the reverse of that experienced in ordinary radiant-heat absorption-methods.

The selection of means, therefore, for induction heating generally points to a circuit of frequency considerably higher than that of our commercial supply, the most suitable frequency being determined by the size and shape, and the arrangements, of the load in the magnetic field.

Melting

In the melting of metals, induction furnaces are divided into two distinct classes; the core, and the coreless types. The core type is simply a transformer having a primary winding core, and single-turn secondary which is the load being melted. To make this type of furnace function, obviously, a complete short-circuited secondary must always be left in the furnace to furnish load for the melting of the new charge. The commercial frequency is satisfactory for core-type furnaces. The useful heating is obtained from the load current in the molten charge, rather than from the hysteresis and eddy currents.

Of course, eddy currents are true electric currents and produce their heat in accordance with Ohm's law, and the load current could be considered as a special case of eddy current where the t^2 appearing in the formula is the diameter of the secondary circuit and the flux density is the flux through the iron core; however, we do not generally think of the load current as a sort of glorified eddy current, but rather of the eddy currents as miniature load currents.

The many ingenious arrangements to improve the coupling between primary and secondary, to raise the resistance of the secondary and reduce the inductance and thus improve the power factor, cover the development of the core-type induction-furnace.

The coreless-type induction-furnace uses the hysteresis and eddy currents produced in the parts to be heated and, obviously, must use a fairly high frequency to produce sufficient heat to melt metals. Referring again to the formulas, we see that the flux is a second-power term and we will at once realize that magnetic materials can be made to carry a much larger flux, say 2000 times larger per ampere-turn of primary, than can non-magnetic materials; accordingly, it is possible to generate sufficient heat in iron parts to heat them very rapidly with a fairly low frequency, as long as they *are* magnetic. A very interesting part of the new induction-heating development, heat treatment below the Curié point, where iron and other magnetic materials lose their magnetic properties, is built around this fact.

In the processing of metals, most heat treatments consist of: First, hardening, that is, heating and quenching from a temperature either within or above the critical temperature range. Second, tempering (also termed "drawing"), reheating after hardening to some temperature below the critical temperature, followed by any rate of cooling.

For example, S.A.E.-1045 0.40 to 0.50 carbon steel draws at 800 to 1300 deg. fahr., depending on the strength and hardness desired. Here the induction heat gives nearly automatic temperature-control; for, a part to be heated to 1100 deg. fahr., let us say, can be placed in a field of definite strength. The temperature rises very rapidly at first up to 850 to 900 deg. fahr. and then much more slowly as the power input falls off with the loss of magnetic properties. The rate of temperature rise is so slow above 1000 deg. fahr. that the exact time required to reach the desired temperature is easily obtained by test for a production furnace which can be safely operated by time control only.

The time usually given to a "draw" for a certain 1½-in. shaft by the "lead-pot" method was 30 min. to insure complete change in the mass of metal. By induction, 8 min. was sufficient time to obtain the same results, as the heat is produced at low frequencies practically throughout the mass.

The use of this induction method for heat treatment of steel certainly will be used in the very near future.

Paint drying is perhaps the latest practical process making use of induction heat. The idea of drying paint from the inside seems desirable to all of us, as the volatile matter next to metal should be expelled before the outside layer seals over to trap these volatiles. All are familiar with paint jobs that have hardened on the outside and never dried underneath. These eventually wrinkle, ruining the surface.

Tests, run some years ago, indicated this paint drying from the inside, out, to be desirable and subsequent experience with production on a large scale fully bears out the statement that the paint baked by the induction method has excellent adhesion and great durability. A large production oven for baking paint on metal wheels is shown in Fig. 1.

Standard oven practice determines the general form of an induction oven with the addition of a special structure for the coils, substituting aluminum rails for the conveyor through the inductor coils and the use of good thermal walls. These induction coils are wound close to the walls, floor, and roof, to form a simple solenoid through which the painted parts are carried on a single-chain conveyor. The heat effect is planned so that the temperature of the parts is quickly raised to the required value. For example, for a 60-min. bake, 5 to 6 min. are required to bring the parts up to temperature. This rapid temperature rise does not wrinkle the paint. The balance of

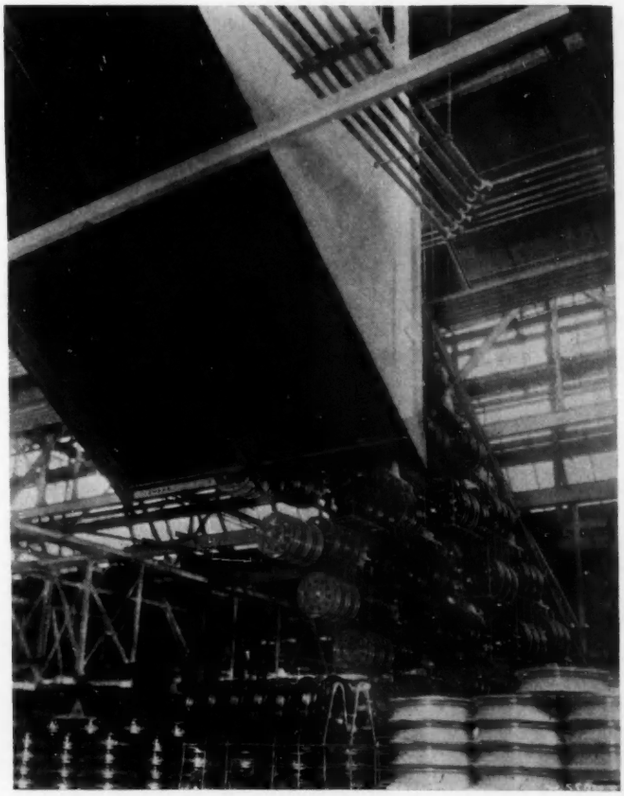


Fig. 1—A Large Production Oven for Baking Paint on Metal Wheels

the oven is designed simply to hold the temperature in the oven constant. This plan is accomplished by a relatively large number of turns for the coils at the head end of the oven with the wires much farther apart, giving a lower flux-density in the remaining part of the oven.

The heating effect that can be given to a certain part is determined largely by experiment, because the radiation from the part is so complex that it is very difficult to calculate. After having determined the number of ampere-turns and frequency of the circuit to raise the temperature in a certain time, the oven coils are laid out. The magnetic circuit within the coil is largely air, and calculations for air-core solenoids of the dimensions fixed by the oven give very close approximations to the impedance of the circuit. The oven does not consist of one long solenoid coil but is made up of six or more coils arranged usually two in series, Y-connected. A delta grouping, however, is also perfectly practical. The purpose of using three phase rather than single phase is two-fold; the motor generator set is slightly lower in first cost but, most important, the change of flux direction at the ends of the coils is very useful in evening-up the heating effects in irregularly shaped parts.

The power factor of these large high-current coils is very poor, 20 per cent or less; so, static condensers are used to correct the power factor to unity in order to reduce the size of the generator supplying the high frequency. Fortunately, the condenser cost per k.v.a. is decreased as the frequency increases; so, 360-cycle, 440-volt condensers cost less than $3.00 per k.v.a.

The production efficiency of the induction oven is very high, as all the electric energy of the high-frequency circuit is used inside the oven. The part being baked is always the hottest spot in the oven. The air circulated and discharged to carry away the fumes of baking is low in amount and 40 to 50 deg. lower in temperature than the parts, as is the oven temperature itself. So, radiation is much less through the oven walls than in conventional air-heated ovens. Further, when no load is going through the coils, no power is being used except that due to the loss in the coils and walls, which is made to balance the radiation.

The most successful control is a simple thermostat which operates the ventilation fan; for, when no work is going through the oven, no fresh air is needed and the fan is cut off. When new freshly painted parts move into the coils, heat is generated in the parts which not only drives off the volatiles but raises the oven temperature, which starts the ventilating fan.

Conclusion

A few very outstanding and successful examples of induction heating may be mentioned. Brass companies are daily melting tons of non-ferrous alloys. The steel companies are producing large quantities of high-melting-point alloy-steels. A large bicycle concern is baking the colored enamel on its bicycle frames and forks. Heat treatment of steel from hardening of safety-razor blades to crankshafts are daily production processes.

The automobile companies are baking paint on tons of sheet metal and over 12,000 wheels daily. They are even drying the entire fabricated body after washing and cleaning to insure complete dryness before applying paint.

Induction heat truly is a practical and versatile tool and should be given consideration for many more jobs in automobile production.

Discussion

A New Rustproofing Method Development Is Described

—W. B. Hurley
The Detroit Edison Co.

IN the last paragraph of Mr. Bailey's excellent paper he stated: "Induction heat truly is a practical and versatile tool and should be given consideration for many more jobs in automobile production."

Recently, there has been developed in Detroit a new method of rustproofing which, although still in a somewhat experimental stage, has considerable promise of speeding up the rustproofing operation, increasing the effectiveness and reducing the cost. Electric induction heating plays a large part in this process.

In this process a motor-generator set furnishes current at approximately 960 cycles of frequency as compared to the normal 60-cycle current.

The parts to be rustproofed are cleaned in the ordinary manner and, after the rinse, immediately pass through an induction coil where they are given a heavy charge of induction heat. This quickly drys off any remaining moisture and thus stops the formation of rust, after the rinse, before it has a chance to start. While still hot, the parts pass into the rustproofing tank, which in this case contains activated phosphates. They immediately enter the field of another induction coil and become heated, facilitating the deposition of a fine-grained coat of phosphate. On leaving the rustproofing tank, the parts pass through another induction coil where they are quickly dried. If desirable, they could then be painted and enter Mr. Bailey's type of induction oven for the final drying.

Such a combination of cleaning, rustproofing, painting and drying, could be worked out very nicely on a continuous-conveyor system and would lend itself admirably to heavy production jobs.

From the tests so far run, this method of rustproofing, as compared to the similar method without the application of induction heat, appears to produce a more highly resistant rustproof film and to produce this film more quickly and with a saving in the amount of chemicals used. The cost of the electricity is a very small item and, where reasonable electric rates prevail, the induction heat could be used for keeping the rustproofing tank at the proper temperature; where electric rates are higher, the tank could be heated with steam and electric induction only used for heating the parts to be rustproofed.

The fineness of the grain of the phosphate coating produced by the induction heating apparently makes the phosphate film denser and more resistant to the penetration of moisture.

This process is used at the Budd Wheel Co. in Detroit in the rustproofing of wheels preparatory to the painting operations.

Loading and Overloading Topics at Transportation Meeting

WITH a registered attendance of members and guests representing nine states, the 1935 S. A. E. Transportation Meeting held at the Palmer House in Chicago, Oct. 10, sustained the high traditions of this congress with respect to value of new contributions to the literature of this important phase of automotive engineering. It was a most harmonious meeting, despite the fact that as usual at times there was sharp difference of opinion on technical matters.

The afternoon session was conducted by the Transportation and Maintenance Activity Committee of the Society, with L. V. Newton, automotive engineer of the Byllesby Engineering & Management Corp., directing affairs. Greetings were brought by Charles O. Guernsey, chief engineer, J. G. Brill Co., Vice-President of the Society representing Truck, Bus and Railcar Engineering, who conducted the evening session; and by L. R. Buckendale, executive engineer, Timken-Detroit Axle Co., Chairman of the axles and wheels division of the Standards Committee.

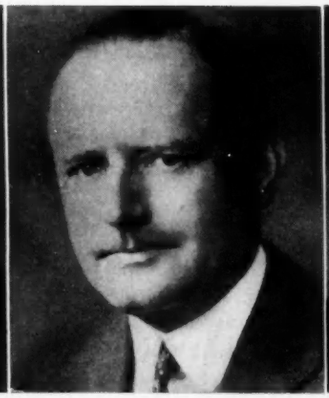
The theme of the afternoon session was the overloading of trucks, and upon this theme an exhaustive paper was presented by J. E. Hale, manager of the development department of the Firestone Tire & Rubber Co., with copious lantern slide illustrations.

"The purpose of this paper," Mr. Hale said, "is to set down the technical, commercial and practical aspects of the factors surrounding the subject of loads to which a tire could be subjected with the hope that the whole subject may be presented in such a way that a logical and sensible answer may be forthcoming to satisfy the belief of those who feel that load ratings are too conservative. In the last analysis, it is the truck owner whom we have to satisfy, so it is proper that we should get clearly at this point the truck owners' viewpoint."

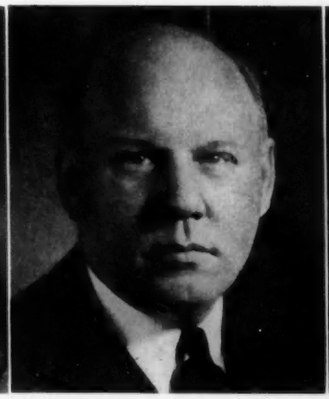
Mr. Hale added that truck and bus engineers have been grumbling a bit because the tire industry has not seen fit to revise its load schedules upward, but the industry could not afford to consider any such step as a revision to bring load ratings up to the point of the average loads now carried because of the psychology surrounding the situation, for the tire people believe the truck industry and truck operators are going to discount any table which is printed. The tire durability curve has been going upward for many years, but Mr. Hale expressed the belief that it would drop precipitately following arbitrary increases in load ratings. So far as his company is concerned, it is very reactionary toward any change in its load ratings.

"In this paper I have elected to refer only to the balloon type of tire and made no mention of the high-pressure tire," said Mr. Hale. "I did this purposely because I feel there is no place for the high-pressure line in our present-day production of modern vehicles. While I recognize that thousands of

J. E. Hale
Talked of tire overloading



L. V. Newton
Chairman at morning meeting



A. J. Scaife
Discussed Truck Loading

F. L. Faulkner
Afternoon meeting chairman

trucks in use are equipped with high-pressure tires which will have to be replaced, it seems to me that the truck, bus and tire industries should be definitely active to see that no future trucks are put out on the high-pressure tires, thereby initiating the moves necessary to gradually retire this type from the market. . . . The high-pressure tire is limited in high speed application from the point of view of tire life, while it of course is known to be satisfactory for slow speed work."

Service of Retreaded Tires

Answering the question as to whether repairs and retreads should be "babied" when put back in service, Mr. Hale said his advice would be to place them where they do not have to transmit power. Practically the only type of operation where he has found it not advisable to use them at all is in the very fastest intercity service.

Telegraphing a brief comment from New York, T. C. Smith, engineer of motor-vehicles and construction apparatus, American Telephone & Telegraph Co., and S. A. E. Vice-President representing Transportation and Maintenance, said in part: "Mr. Hale upholds the classic theme of the manufacturers that overloading tires is uneconomical. I wonder if the answer is quite as simple as that?"

K. D. Smith, technical superintendent, B. F. Goodrich Rubber Co., said, generally speaking, his observations showed results similar to Mr. Hale's tests. Burgess Darrow, development manager of the Goodyear Tire & Rubber Co., endorsed Mr. Hale's plea for dropping the old high-pressure tire on trucks in favor of balloons. Comment by Sidney M. Cadwell and A. W. Bull, United States Rubber Products, Inc., concluded: "To say, that because overloading is common, we should raise the ratings to make the standards fit the practice, is as illogical as to argue that where reckless driving is common we should modify traffic laws to permit it." A prepared comment by Leo Huff, Pure Oil Co., who was not able to be present, said in part: "It would seem reasonable to throw overboard our excessive faith in rating tires purely on a dead-load basis and apply tires of such size as may prove adequate and provide the most reasonable cost per ton mile."

High-Pressure Tire Problems

Commenting on Mr. Hale's paper, Mr. Newton agreed that high-pressure tires are no longer desirable on new vehicles. They must continue to be manufactured, however, he pointed out, for some time to come for those trucks and buses now so equipped.

"I do not believe," Mr. Newton said, "that intermediate balloon tires are necessary—the spread between the various sizes now obtainable being too great."

Continuing, he stated: "I cannot subscribe to the use of larger cross-section lower air-pressure tires on trucks with a rim diameter of 18 in., as has been suggested. Overall width of trucks is pretty well established at 96 in. Wider cross-section tires will certainly mean narrower frames and wider axles. This will interfere with our standard body measurements, in fact will destroy the standardization now in effect. I do not believe the advantage of lower air-pressure tires are worth the loss of body dimension standards and the expense to which the truck and axle manufacturers will be put to."

The manufacturer's point of view on loading trucks was presented at the evening session by Past-President A. J. Scaife, consulting field engineer, White Motor Co., in a paper entitled "Economical Loading and Operation of Motor Trucks." The meeting also was a session of the Chicago Section of the Society, and about 25 members of the Transportation Club of Chicago were present by special invitation to get the operators' views. Chicago Section Chairman R. T. Hendrickson, Hendrickson Motor Truck Co., opened and closed the session, which was directed by F. L. Faulkner, Armour & Co., vice-chairman of the Chicago Section.

Mr. Scaife said that the problem of economical loading of trucks is not only the concern of the truck industry, but also of users, of legislators and highway officials. The method of rating carrying capacity he said was more or less guesswork and confusing. He reviewed the "roadside clinic" in Maryland as disclosing for one thing that it is definitely indicated that loading in excess of rated capacity is greater in the case of small trucks than that of large ones.

"On the average," he pointed out, "the 1½-ton trucks will be found carrying 1 to 1 2/3 times as much, while the 5-ton trucks carry just about their rated capacity. In fact, the smaller trucks are loaded to 4, 5 and even 6 times their rated capacity, while the larger ones are seldom loaded beyond their rated capacity."

No Economy in Overloading

Reviewing the many factors that enter into determination of an adequate method of rating carrying capacity, Mr. Scaife finally reached the conclusion "that there is no economy in the purchase or use of a low-capacity, low-priced truck, heavily overloaded, in comparison with a truck of higher price and carrying capacity when all of the factors are taken into consideration."

Leading the discussion of Mr. Scaife's paper, Fred B. Lautzenhiser, transportation and sales engineer, International Harvester Co., expressed the belief that, generally speaking, there may be needless alarm at the much-discussed tendency toward overloading. "Of course," he added, "there are many specific cases of overloading that are almost unbelievable; however, surveys show these cases to be negligible and an extremely small percentage. I am inclined to ride along with the state of Rhode Island in its requirement for all vehicles or combinations to be able to climb a 4 per cent grade at a speed of 20 m.p.h. That would unquestionably cure the evil of overloading if it were enforced."

Past-President B. B. Bachman and Vice-President of Engineering, Autocar Co., said there is no answer as yet in sight, but that Mr. Scaife's paper made important contributions toward a solution. He upheld Mr. Scaife's view that weight of chassis is one of the most important factors in rating capacity.

M. C. Horine, Mack Trucks, observed that Maryland trucking conditions are not at all typical of the country. As for the Rhode Island requirement, he said it is not overly severe and a sensibly loaded truck need not fear meeting it. It has not been a success because a physical test is wrong, especially when enforcement is in the hands of an ordinary police officer.

Truck Rating Needed

Mr. Newton pointed out that Mr. Scaife's paper again focuses attention on the subject of truck rating, and expressed the hope that a standard rating chart may be evolved by the S.A.E. which will take into consideration the capacities under normal and shock load of such parts of the vehicle as axles, springs, spindles, axle shafts and frames.

Horsepower requirements, also, Mr. Newton thinks, should be set forth to meet reasonable ability requirements.

Transmissions and Research Share Spotlight at Tractor Meeting

THAT the Activity has outgrown its swaddling clothes and has become a permanent and virile force for the advancement of its particular part of the automotive industry was proved beyond doubt during the Third S.A.E. National Tractor and Industrial Power Equipment Meeting, held Oct. 11-12 at the Palmer House in Chicago. As a measure of the growth of the Activity it may be said that this third meeting commanded the presence and participation of an increased number of members distinguished in their professions. Some had gone to Chicago a day earlier to attend the 1935 S.A.E. Transportation Meeting, Oct. 10, and others to attend the 42nd annual convention of the Farm Equipment Institute, Oct. 9-10.

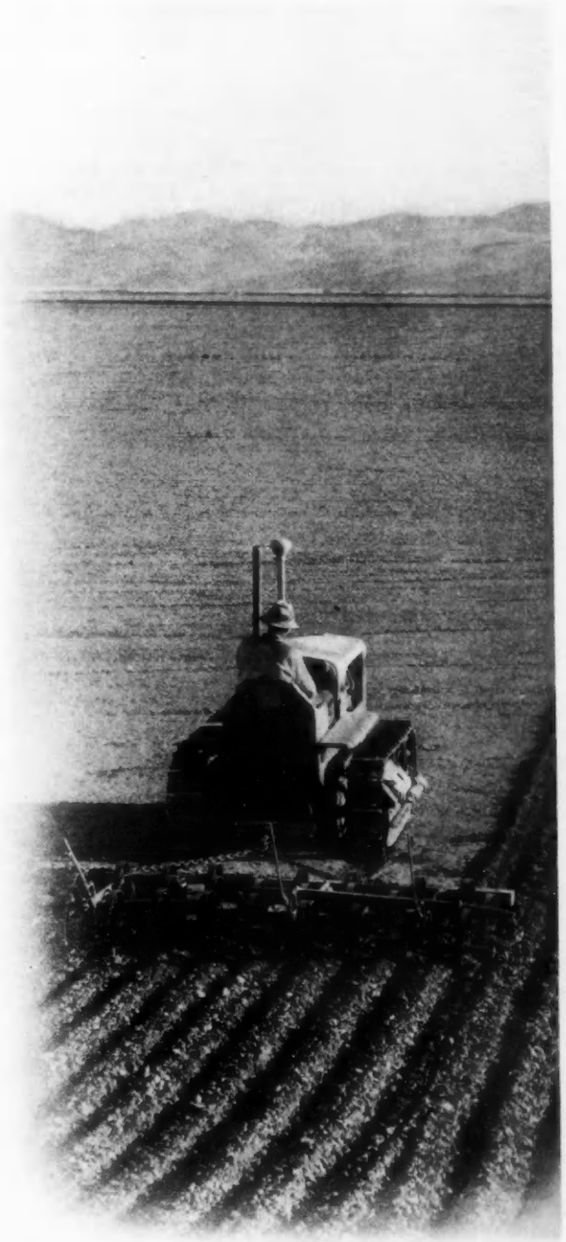
MacFarlane Extends Greetings

This made it possible for W. C. MacFarlane, president of the Minneapolis Moline Power Implement Co., newly elected president of the F. E. I., personally to extend greetings at the first session, which was devoted to research and was under the chairmanship of C. E. Frudden, chief engineer, tractor division, Allis-Chalmers Mfg. Co. Mr. MacFarlane said in part:

"It is a pleasure for me to meet with you for a few moments and to try to express the importance of the S. A. E. to the F. E. I. Were it not for the S. A. E. and the subsequent organization of the A. S. A. E., the rapid forward strides that have been made in power machinery in our industry in the last decade would not have been possible. . . . The research work done by your organization is helping us to solve the problems that are confronting our industry in the development and satisfactory operation of practically all of our products. . . . It has always been a great deal of satisfaction to me to find that, without exception, the engineering fraternity is always so willing to interchange information, as between competing plants in the industry, and I believe that it is only by this willingness to cooperate to the mutual benefit of all that the immense strides forward have been made."

In the absence of William B. Stout, Detroit, president of the Society, who was unable to reach Chicago in time, John A. C. Warner, secretary and general manager, New York, extended the Society's official greetings, and also was privileged to present the nominee for the 1936 presidency, Ralph R. Teetor, Perfect Circle Co., and present Chairman of the Society's Research Committee.

In a paper on "Research in the Automotive Industry," T. A. Boyd, head of the fuel section, General Motors Corp. Research Division, saying there is a similarity between the automobile and the tractor in respect to technical needs, ran



through the history of the motor car to show, first, that it was research that gave us the automobile in the beginning; second, that all of the improvements in cars were made through research; third, that continued improvements demand a consistent continuation of research; and, fourth, that as the car itself had got better and better, the kind of effort needed to improve it still further has had to be advanced from the elementary form of experimentation employed in the early days to include more of the original of the pioneering work of research.

Research Balks Depression

"One of the major reasons," Mr. Boyd declared, "why the automobile industry is doing so much to lead the country out of depression is because of the accurate knowledge gained through this highly diversified research; that is to say, it is because of this knowledge coupled with the optimism, the initiative, and the courage of the leaders of the automobile industry in acting upon such new knowledge, once it has been obtained.

"Here I should like to mention the fact that it is important for the management of an industry to understand research, and to appreciate its possibilities and its limitations. If those who really decide what is to be done in any business do not have an adequate appreciation of research and the part which it can play in their business, there is little use for them to maintain a research laboratory, because the products of the research will not then be used, no matter how good they may be. And further, if the leaders of a business do not have a proper understanding of research, some things may be done in the laboratory which, while good enough in themselves, perhaps, will be of no use in their particular business."

Mr. Boyd added, "The reason why the automobile business is so full of life today is that the men who have given it direction have never been too conservative to try a new thing in any phase of the business whenever one came along that appeared to be worth trying." He called attention to the effect of research in more dependable, more powerful, more economical, lighter and smoother engines; better means of carburetion, of lubrication, of ignition, of cooling; improved transmissions, easier and safer steering devices, better brakes, better springs and suspensions. All within the past eight years the boost in compression pressure of automobile engines has been 40 per cent; the boost in brake mean effective pressures at maximum horsepower, 25 per cent; and the boost in horsepower per cubic inch of engine displacement, 60 per cent. So gradually and consistently have the improvements come along that it is only by driving a current model in direct comparison with a car that is three to four years old that one is really able to properly appreciate the magnitude of the changes. It is by such gradual evolution, rather than by long, intermittent strides forward, that the automobile or any other technical product advances, he said.

Current Research Objectives

"Upon what is research thinking?" Mr. Boyd asked, answering his own query: "We need still better and lighter engines; more perfect transmissions, better brakes, better springs, still better finishes, and the like. We need glass that is really 'safety' glass. We need to know more about the strains set up in metals by heat, and we ought to know how to run engines on leaner fuel mixtures, and so at once to improve economy and to cure the stinking of engine exhausts which someone has dubbed 'highway halitosis.'

"This is the reason why those who now are trying to improve automotive transportation still further have come to consist not only, as at first, of conventional engineers. It is why they now include also men capable of connecting fundamental and pioneering researches in such sciences as chemistry, physics and mathematics—and even as botany and bacteriology."

Mr. Boyd also pointed out the need of customer research. He closed by saying: "So comes the end of this effort to answer the question, 'What's the use of all this research business?' In our motor car business the use of research is to make sure that the future of the automobile industry will be as glorious as its past."

The paper aroused an animated discussion, all comment being oral since advance copies could not be made available.

Metallurgy is Topic

The Friday afternoon session was devoted to metallurgy. L. B. Sperry, International Harvester Co., scheduled to serve as chairman, was called to Europe a few days before the meeting, and Col. O. B. Zimmermann, of Johnson & Co., consulting engineers, acted in his stead. The subject, "Some Factors Affecting the Performance of Tractor Gears," was discussed in a paper by H. W. McQuaid, Republic Steel Corp.

"One of the first problems confronting an engineer in gear design is the choice of materials," Mr. McQuaid said. "There are, of course, advocates of all types of steel, depending on design and service. It is generally conceded in the automotive field that the case-hardened gear will out-perform an oil-hardened gear, although many millions of passenger-car and truck transmissions are made from an oil-hardened, high carbon steel with a cyanide-hardened surface. These gears depend entirely on the five-thousandth of an inch of cyanided

Tractor Activity Nominates Vice-President for 1936

A. W. Lavers, chief engineer, tractors and engines, Minneapolis Moline Power Implement Co., has been nominated for Vice-President of the Society for 1936, representing the Tractor and Industrial Power Activity.

This nomination was made by the Activity nominating committee during the Tractor and Industrial Power Equipment Meeting in Chicago, Oct. 11 and 12; the action of this committee having been delayed until that time in the absence of an earlier business session of that Activity.

Other S.A.E. nominees for 1936 were announced on page 16 of the October S.A.E. JOURNAL.

surface for successful performance. In the heavier duty applications, the carburized alloy gear stands almost alone. Modern gear performance is based primarily on good design and accurate cutting, the benefits of which would be lost if we had to put up with the distortion that results from the old type of carbon steel. . . . The real problem so far as the tractor engineer is concerned becomes one of selecting the carburizing grade of steel which is the most economical in final cost and which will in service give a thoroughly satisfactory performance."

Gear Paper Discussed

Typical comment on the paper was that by Gordon T. Williams, metallurgist, Cleveland Tractor Co., who said: "Mr. McQuaid has given us a splendid general discussion of certain factors to be considered in tractor gear manufacture, as we might expect from his wealth of experience and understanding." H. Bornstein, Deere & Co., added the thought that economical manufacture of good gears involved the cooperative effort of the designer, steel-maker, forger, machiner and metallurgist. M. L. Frey, John Deere Tractor Co., agreed with Mr. McQuaid that service tests are the only true tests of gear performance, but said he feels that static and dynamic tests in the laboratory have a definite place. J. Fletcher Harper, Allis-Chalmers Mfg. Co., referring to gear forging and heat treatment, said: "I would like to make an appeal to all gear designers present to please have a little consideration in the matter of shape and the use of unequal sections. Gears must be quenched to harden, and when light and heavy sections join, the difference in cooling rates compels distortion. Sharp corners do not help grain flow and cause trouble in quenching. These points are well known to everyone, but are disregarded so often under the excuse of weight, space, etc., while from the practical life standpoint they are as important as tooth pressure." Mr. Harper also confirmed the speaker's statement that the true test of any gear is its service record under field conditions.

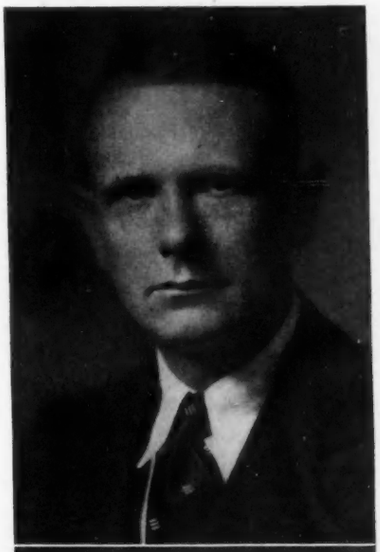
E. F. Davis, Warner Gear Co., said: "Not many years ago it was firmly believed that cyaniding made noisy gears, and many eminent men connected with the gear industry publicly and privately said that the cyanided gear was not feasible. Yet today 90 per cent of all passenger car gears have cyanided surfaces. The outer layer is largely of nitride of iron and this produces the extremely good wearing surface which characterizes the cyanided gear. This area is only a few tenths of a thousandth, but is extremely hard. The remainder of the case is a mixture of nitride and carbide."

To conclude the second session, Secretary Warner gave an interesting 10-minute motion picture presentation made with his own camera at the 1935 Summer Meeting of the Society at White Sulphur Springs, West Va. The antics of President Stout's Scarab were especially interesting and productive of applause.

McCormick Lauds Krieger

Elmer McCormick, chief engineer, John Deere Tractor Co., chairman of the meetings committee of the Activity, presided as chairman of the final session Saturday, Oct. 12. Mr. McCormick paid high tribute to Vice-President C. G. Krieger for bringing the Activity from scratch to a position of eminence, and especially for his efforts in making the third meeting so effective in program planning. As chairman of the meetings committee, Mr. McCormick also suggested that his committee be given new thoughts and appealed for sugges-

Three of Tractor Speakers



T. A. Boyd
Research his subject

H. W. McQuaid
Talked tractor gear sets

A. W. Frehse
Visioned transmission future

tions for future programs. Secretary Warner, who had remained through the sessions, at this point praised the exceptionally high standard of papers presented at the meeting as well as the prepared and oral comment made in the discussions.

Tractor Transmission Trends

The closing session was devoted to transmissions, the first paper being presented by Otto R. Schoenrock, O. R. S. Engineering Co., who described and illustrated recent tractor transmissions and their trend. As tractor transmissions generally are a unit with the rear axle or closely associated, the paper was intended to cover all mechanism from the clutch shaft to rear wheels. He said tractors are now passing through the same stage that the automotive industry did some years back, with varying locations of these units. He incidentally expressed the belief that the next change in automobile practice will combine the rear axle with the transmission, clutch and engine for further simplification and improved performance.

"In the future greater attention will be paid to good lines and proportions," Mr. Schoenrock said, referring again to tractors. "It creates sales appeal. Just because it is a tractor does not mean that it cannot be made to look good. It is not impossible to make a transmission case which has a good appearance, if serious thought is given in designing it. . . ."

W. H. Worthington, John Deere Tractor Co., commented that while repairs always will be a matter of concern, tractor designers are getting away from the necessity for repairs as designs and materials improve, but it must not be lost sight of that when repairs are necessary it should be possible to make them at a minimum of expense for labor and parts.

A. W. Frehse, Chevrolet Motor Co., stimulated discussion with a paper reflecting some thoughts on present-day automobile transmissions. He made the observation that, peculiarly enough, the automobile transmission is "on the way out" while the tractor transmission is just "on the way in." Most of the development work done today on automobile transmissions is confined to the use of helical gears in various combinations. Helical gears, he said, are the best type that can be produced today and nearly all modern gear-producing machinery is being refined and developed to produce better helical gears, adding that the reasons are perfectly obvious.

Mr. Frehse said in conclusion: "I don't know what the automobile transmission will look like in the far future, but I think there are now available useful mechanical principles from which we can build far better transmissions than we are driving today. It all depends on whether the automobile manufacturers set out to furnish them or the public demands them. We are doing things today that ten years ago would have been considered impossible."

Heat Treatment Important

S. O. White, chief engineer of the Warner Gear Co., supplemented Mr. Frehse's remarks, adding the thought that the question of proper and uniform steels and heat treatment, a high standard of shop practice and workmanship, are all as important as the design. "It is by using these to the best advantage," he said, "that today's transmission designs are mere pocket editions in size, compared with those in use 15 and 20 years ago. There seems to be no question that these . . . could be well applied to the tractor. Some of these practices are expensive, unless used in very large quantity production, and this is perhaps one of the stumbling blocks in the way of the development of tractor transmissions. Their application, method of installation, power requirements and use, cover such a tremendous range, that standardization of design to permit large quantity runs of gears is very difficult. Progress, however, is being made, and it is to be hoped that an interchange of ideas and experiences on such occasions as this will help toward a solution of the problems involved."

J. E. Padgett, assistant general manager, Spicer Mfg. Corp., observed that the papers by Messrs. Frehse and White bring out the beautiful precision of engineering and manufacturing which is accomplished in high-production passenger-car transmissions.

Knowledge of Past Needed

"In truck and tractor transmissions the quantities are small and of great variety, so that it is often more important that the designing engineer have a wide knowledge of past results and performance, so that he can produce an article that will stand up well. All engineering calculations are subject to factors of safety, and it is only experience that will give the correct factor. This is especially true in tractor transmissions where the majority of use is in gear and not a minimum use such as the passenger-car transmission has in gear."

Collaborating in comment, S. M. Ransome and J. P. Breurer, Barber-Colman Co., spoke of the importance of correct transmission gear mounting. Tolerances are already so slight that the gear manufacturers are considerably ahead of the profession and are, in fact, approaching so closely to the irreducible minimum of absolute accuracy that further progress will necessarily have to be small.

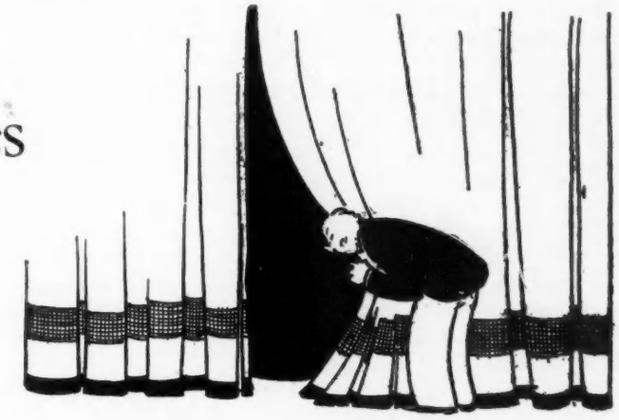
Gear Lubrication Problems

B. W. Keese, Wisconsin Axle Co., said gear stresses have been constantly increased to a point where high film strength oils are most necessary for satisfactory lubrication and cushioning. "Lubrication of gears is perhaps today a larger problem than gear manufacture and many a good gear contact has been ruined by poor oil," he said. "I have seen gear assemblies with marked evidence of scuffing relubricate with proper pressure lubricants and actually polish down to a good contact, completing a service of normal life and wear. Unfortunately, many fillers now used to obtain extreme-pressure oils or qualities necessary for gears are not only destructive to the bearings, but do not have the property of mixing with oils of other makes. At the present time, it is believed that maximum gear stresses will no longer be dependent upon gear material, but rather contingent upon a suitable lubricant with general distribution."

L. A. Bixby, manager, Clark Equipment Co., transmission division, brought the discussion to a close by expressing the thought that the use of inspection instruments and tools is a very important and timely subject. "It becomes very important to be able, day after day, to check parts and to be able to get uniform readings and information that will help to keep production departments producing parts as they should be and getting the final results that we expect. Very often considerable expenditures are made for highly precision production machines without consideration as to how the inspection department is going to maintain the proper checking of the production parts. I think this point is one we all should watch to see that the equipment is well balanced to produce and check production," he said in conclusion.

Behind the Scenes

With the Committees



Oiliness Research Program

A TENTATIVE program for cooperative research on crankcase oil oiliness has been drafted by a subcommittee and is being circulated among the members of this group. The program is the work of the Crankcase Oil Oiliness Research Subcommittee, J. B. Macauley, chairman, which was established by Council action on Sept. 19, following a recommendation of the Research Committee made at the last Summer Meeting. Other members of the Subcommittee are: D. P. Barnard, A. L. Beall, O. C. Bridgeman, Opie Chenoweth, J. B. Fisher, H. F. Huf, W. S. James, G. M. Maverick, H. C. Mougey, W. A. Parkins, C. R. Paton, Andre A. Priester and B. E. Sibley.

Actual preparation of the program was in the hands of a steering committee with A. L. Beall as chairman. Subsequent to approval by the Subcommittee the program will be circulated to those companies which are to be invited to participate in the cooperative tests.

Auto Headlight Inspection Code

IN cooperation with the Highways Research Subcommittee of the Research Committee, the Lighting Division of the Standards Committee is working on the development of a simple code that will provide an adequate means for inspecting automobile headlight adjustments at road inspection

stations as a part of a general program for increased safety in motor vehicle operation. A tentative draft code is now under consideration.

The committees concerned with this work are endeavoring to have a completed code available soon to provide a generally accepted uniform basis for road inspection of headlights throughout the country.

Aviation Gasoline Detonation Report

THE report of the Cooperative Fuel Research Aviation Gasoline Detonation Subcommittee has been approved by the Cooperative Fuel Research Steering Committee and will be presented to the American Petroleum Institute by C. B. Veal, research manager of the Society and secretary of the C.F.R. Committee, at its annual meeting in Los Angeles, November 11-14.

This report covers the results of tests made to ascertain whether octane number determinations made by the C.F.R. Motor Method (A.S.T.M. Designation D537-34T) of rating motor fuels correlate satisfactorily with the behavior of widely different types of aviation fuel in representative full scale aircraft engines. These tests were made with four multicylinder aircraft engines by the Wright Aeronautical Corp., the Pratt and Whitney Aircraft Co., the Lycoming Manufacturing Co. and the National Bureau of Standards.

The Subcommittee, at its meeting of Sept. 9, recommended a further program for full-scale engine detonation work with aviation fuels above 87 octane number. This was approved the following day by the C.F.R. Committee.

Lieut. C. F. Coe of the Bureau of Aeronautics of the Navy Department, Lieut. F. D. Klein of the Materiel Division of the Army Air Corps and Dr. J. H. Parkin of the Canadian National Research Council have accepted membership in the A.G.D. Subcommittee.

Safety Glass

THE development of a code covering definitions and testing requirements of safety glass, upon which the Society is cooperating, is nearing completion under the procedure of the American Standards Association.

This code is being developed by representatives of a large number of groups interested in the project from many angles. It is expected that its application and use will have an important influence on the safety of motor vehicles. There has been a pronounced need for such a code to serve as the basis of uniform safety glass requirements in the several states.

Form Joint Committee

THE Society has cooperated with the American Society for Testing Materials and the American Society for Metals in the organization of a joint committee to review and bring up to date the definitions of terms relative to the heat treating of steels. The following members of the Iron and Steel Division of the Standards Committee are the Society's representatives: E. F. Davis, vice-chairman of the Division; A. L. Boegehold and George L. Norris.

Brake Report Available

A REPORT on prevailing condition of passenger-car brakes, prepared for the Brake Committee under the direction of Prof. E. H. Hamilton of New York University, has recently been mimeographed and circulated to members of the Committee. The report includes a supplement covering the results of a study made for the Highways

Research Subcommittee, indicating relative braking effect on the right and left sides of the vehicle. This will be helpful to the Brake Committee in establishing tolerances.

Riding Comfort

THE article, "Criteria Set for Riding Comfort," by R. W. Brown, chairman of the Riding Comfort Research Subcommittee, and Dr. H. C. Dickinson, chief, Heat and Power Division, National Bureau of Standards, which appeared in the August issue of the S. A. E. JOURNAL, has been brought to the attention of members of the Subcommittee and of others in the industry who have indicated an interest in the work of the Committee. Comments and suggestions that have been received are being analyzed for presentation to the Subcommittee at its next meeting.

Circulate Wheel-Alignment Data

THE basic definitions for Wheel Alignment and the manufacturers' wheel alignment specifications, which appeared in the September issue of the S. A. E. JOURNAL, have been sent to the leading automotive trade journals with the request for publication.

The Front-Wheel Alignment Research Subcommittee is continuing its cooperative work with the Highways Research Subcommittee in formulating the wheel-alignment phase of the recommended procedure for motor-vehicle inspection.

Crankcase Oil Stability Tests

A COOPERATIVE program of ring-sticking tests using a group of three test oils has been arranged by the Steering Committee of the Crankcase Oil Stability Research Subcommittee.

Oil samples supplied by three cooperating oil companies

will be packaged in 5-gal. unmarked cans and distributed to the participants under a code number. The characteristics of the coded oils will be as follows: A non-ring-sticking oil, a ring-sticking oil and an oil which is neutral with respect to these characteristics.

All laboratories in a position to participate actively in the committee's work are invited to cooperate in rating the oils according to their individual test methods. Data from these tests will be collected for a comparison of results by the various testing methods now in use.

The Wright Aeronautical Corp. is planning to run the oils in tests on aircraft engines. It is hoped that other aircraft engine laboratories will similarly cooperate.

E-P Lubricants Testing Machines Delivered

FOLLOWING the completion of the acceptance tests the Extreme-Pressure Lubricants Machines have been delivered to the purchasers. The tests were carried on at the plant of the Highway Trailer Co. under the direction of S. A. McKee of the National Bureau of Standards.

Vapor Lock Procedure

THE Cooperative Fuel Research Volatility Subcommittee, at the request of the Cooperative Fuel Research Steering Committee, is collecting data on the various methods now in use for conducting vapor lock tests. This material will be used in developing a standard procedure for this type of test.

Motorboat Shaft Couplings

SEVERAL years ago the Society adopted standards for motorboat propeller shaft couplings based on tapered shaft ends (1935 S.A.E. HANDBOOK, pp. 73-76). Because tapered shaft ends are little used this standard has found only limited use. The Motorboat and Marine Engine Division of the Standards Committee is now correlating data received from cooperating manufacturers with view of revising the present standard and to provide a series of couplings for straight shaft ends now commonly used.

Engine Testing Forms

THE matter of revising the standard forms for recording engine performance, which the Society has provided to engine manufacturers and users for a number of years, is now being considered by the Gasoline Engine Division of the Standards Committee. This is in keeping with the practice of revising these forms periodically to keep pace with the development in engine design and performance. Particular attention will be given at this time to improving the correction formula that is given in the forms.

Speedometer Standards

A SUBDIVISION of the Parts and Fittings Division of the Standards Committee, under the Chairmanship of F. G. Whittington, is developing recommendations for a standard method of calibrating motor vehicle speedometers and is reviewing the present S.A.E. standard for speedometer drive shaft connections (1935, S.A.E. HANDBOOK, p. 26).

This program includes a study of the variations from accurate readings at various car speeds and of a method of testing that can be recommended.

Automobile Fuses

THE desirability of revising the present S.A.E. Standard for Fuses (1935 S.A.E. HANDBOOK, p. 115) is now being investigated by the Electrical Equipment Division of the Standards Committee. It is expected that a subcommittee will be appointed to study the results of the survey with view of making recommendations.

Ball Bearing Standards

THE standard for ball bearings, with particular reference to the thread limits for ball bearing lock nuts (1935 S.A.E. HANDBOOK, pp. 158-159), is now under consideration by ball bearing manufacturers with view of bringing these thread limits more in line with the American Standard for screw threads as adopted by the Society and approved under the procedure of the American Standards Association. As definite recommendations become available they will be

referred to those in the industry who would be interested, before any changes are finally adopted by the Society.

Highways Research Subcommittee

A TENTATIVE draft of the Recommended Practices for Motor-Vehicle Inspection, including revisions by the Lighting Division of the Standards Committee to eliminate conditions which would permit improper vertical aiming of lights, and changes in steering gear requirements has been circulated by the Highways Research Subcommittee. Copies have been submitted to members of this committee and to the following: A group in Front-Wheel Alignment Research Subcommittee; the Brake Committee; an interested group of motor-vehicle enforcement officials; and through R. S. Burnett, standards manager, to the following committees for which he is staff contact—Transportation and Maintenance Activity Committee; Truck, Bus and Railcar Activity Committee; and the Lighting Division, the Motorcoach and Motor Truck Division, the Passenger Car Division, the Tire and Rim Division, and the Transportation Division of the Standards Committee.

The replies from these groups are being carefully considered and analyzed with the view of further revising the recommendations should the desirability of revisions be indicated.

S. A. E. Pacific Regional Meeting

San Francisco, Calif., Nov. 18 & 19
Hotel Whitcomb

Auspices of the S.A.E. Pacific Coast Sections

TENTATIVE PROGRAM OF SESSIONS

Monday, November 18

Chairman, J. M. EVANS

10:00 A.M. **Fuel Applications Session**

"Butane Application and Performance in Automotive Service"—P. W. ENSIGN, Ensign Carburetor Co., Ltd.

"Practical Gasoline and Oil Problems in Trans-Pacific Flying Operations"—JOHN C. LESLIE, Pan-American Airways, Pacific Division

2:00 P.M. **Caterpillar Tractor Co. Plant, San Leandro**

"Diesel Injection in the Light of Fuel Properties"—C. G. A. ROSEN, Caterpillar Tractor Co.

6:30 P.M. **Dinner**
Athletic Club, Oakland

8:00 P.M. **Transportation and Maintenance Session**

Chairman, WILLIAM H. FAIRBANKS

"Diesel Fleet Operation and Maintenance Problems"—C. T. ANTHONY, Pacific Freight lines.

"Automotive Fleet Maintenance Problems on Pacific Coast"—S. B. SHAW, Pacific Gas & Electric Co.

Tuesday, November 19

10:00 A.M. **Fuels and Lubricants Testing Session**

Chairman, J. R. MACGREGOR

"Diesel Fuel Knock Testing"—T. B. RENDEL, Shell Petroleum Corp.

"Gasoline Knock Testing"—C. F. BECKER, Associated Oil Co.

"Extreme Pressure Lubricants Testing"—G. L. NEELY, Standard Oil Co. of California

2:00 P.M. **Excursion**

6:30 P.M. **Dinner—Whitcomb Hotel, San Francisco**

8:00 P.M. **Standards and Research Session**

Chairman, A. G. MARSHALL

"Cooperation the Keystone of S.A.E. Research"—C. B. VEAL, manager, Research Department, S.A.E., New York.

"The Standards Road to Profits"—R. S. BURNETT, manager, Standards Department, S.A.E., New York.

S.A.E. Professional activities cooperating on program

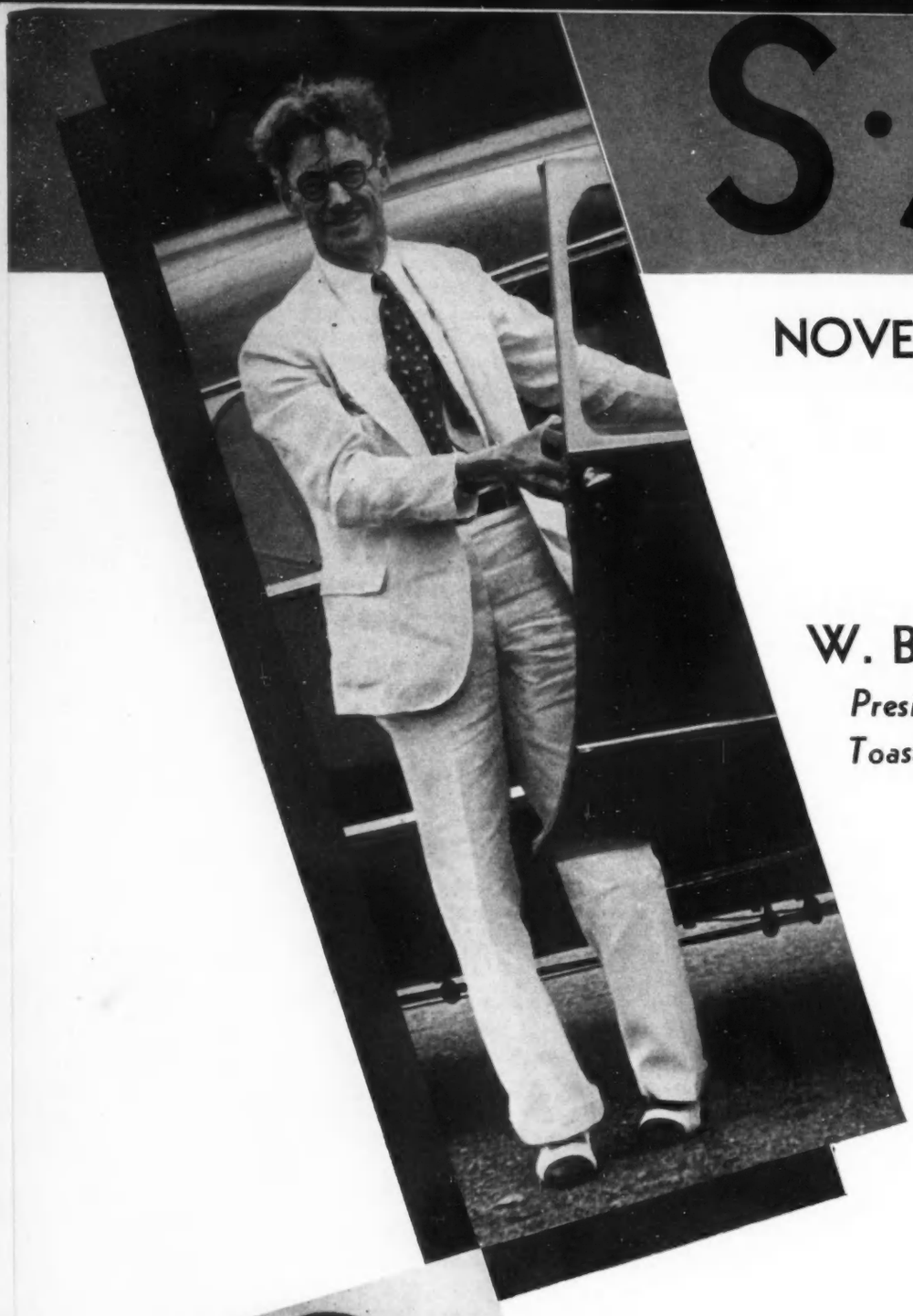
Papers and plant visits of interest to members in the fuels & lubricants, tractor, Diesel and transportation & maintenance fields

If you are going to be on the Pacific Coast at the time of the meeting—if you are a Pacific Coast member—

▶ ▶ ▶ ▶ Plan to attend!

S·A·E

NOVEMBER 4, 1935 •



W. B. STOUT

President of the Society
Toastmaster

"Senator" FORD

"Stumbling over the New Models"

ANNUAL DINNER

HOTEL COMMODORE • NEW YORK

- - - - *and* The March of TIME!

Radio's most dramatic program . . . . *before your eyes* . . . . at the S. A. E. dinner . . . . the *first time outside* of the Columbia studios . . . . world events made real by the actors and producers of this most exciting and human broadcast . . . . see the original cast IN ACTION!

- **WAR** - - today's bitter clash of World Powers
- **BUSINESS** - - rushing on in strident cadence
- **PERSONALITIES** - who make first page NEWS

COME — SEE — HEAR this famous Broadcast;

THE MARCH OF TIME

News of the Society

Stout Bases Progress On Sound Research

● **Washington**

With S.A.E. President William B. Stout and Secretary and General Manager John A. C. Warner as guest speakers and honor guests at a dinner preceding the meeting, the Washington Section got away to a fine start for its 1935-1936 season on October 7.

President Stout, speaking on "Romance of Research", recalled many of his accomplishments in research work in which precedent was forgotten, old assumptions discarded and scientific actualities made the basis of procedure. He stressed the importance of intelligently controlled research and experimental work which he considers the only sound basis of progress. He also spoke of the importance of transportation which he believes includes 85 per cent of the world's activities under both peace and war conditions. He stated that as a direct result of modern, scientific research, there are now available twenty times as many new features for new model cars as were available for the new models of four or five years ago. Mr. Stout showed some interesting moving pictures of his new "Scarab" in action, informal scenes at White Sulphur Springs meeting, and of the "Railplane", the "Skycar" and a new 24-passenger bus.

Speaking on "Automotive Engineering Conquers the World", Mr. Warner presented a verbal excursion through the realm of automotive engineering accomplishments well illustrated with slides and motion pictures. He stressed the point that the accomplishments of the industry are taken for granted by many persons and emphasized the Society's position as one of the important "living" agencies in the world of transportation.

After pointing out that the Society included members in 35 countries and on every continent, Mr. Warner conducted his hearers on a tour over the highways of Europe, Africa and South America. In outlining automotive engineering accomplishments he pointed to records recently made on the salt beds of Utah and the use of trucks in building the Boulder Dam, of the radical transportation changes being performed by the motor bus in New York City, and of the literal unrolling of improved highways by means of a cotton foundation—all products of the genius and perseverance of automotive engineering.

The meeting was held at the University Club. At its conclusion all were served with doughnuts and cider.

Blanchard Traces 1936 Car Trends

● **Detroit**

Members attending the Oct. 21 meeting of the Detroit Section at the Book-Cadillac Hotel were given a preview of the 1936 cars by Harold F. Blanchard, technical editor, *Motor*. Peter Altman presided introducing Harold T. Youngren who introduced the speaker.

Mr. Blanchard opened by discussing the trends in body design and exterior finish of the new cars. He followed this with a discussion of the engines (noting that for the first time in many years there has been no general increase in horsepower or compression ratios), the trend toward hydraulic brakes, the increased use of overdrive transmissions, torsionally stiffer frames, etc. From these general observations Mr. Blanchard went to the individual models pointing out the outstanding changes for 1936.

Following Mr. Blanchard's paper Walter T. Fishleigh conducted the discussion which was of outstanding interest. Among those participating were Stuart G. Baits, assistant general manager and chief engineer, Hudson; Ernest W. Seaholm, chief engineer, Cadillac; C. R. Paton, chief engineer, Packard; Harry T. Woolson, chief engineer, Chrysler; Floyd F. Kishline, chief engineer, Graham-Paige; Harold T. Youngren, chief engineer, Oldsmobile; and Frank E. Watts, chief engineer, Hupmobile.

The meeting and dinner preceding it were well attended.

Airplane and Engine Advances Charted

● **Metropolitan**

Four hundred aeronautical engineers, automotive engineers and engineering students attending the Oct. 15 meeting of the Metropolitan Section at the Roger Smith Hotel were addressed by John H. Geisse, chief, Aeronautical Development Section of the Department of Commerce, and Arthur Nutt, vice-president of engineering, Wright Aeronautical Corp.

Mr. Nutt, the first speaker, discussed the development of engines suitable for private airplanes. He then introduced Mr. Geisse.

The subject of Mr. Geisse's talk was the activities of the Aeronautical Development Section, Department of Commerce. He described the general purpose of the Section, its method of operation and discussed the results which have been obtained on some of the new experimental, low-priced aeroplanes. Mr. Geisse recently piloted a Waldo Waterman tailless plane from Santa Monica, Calif., to Washington, D. C. A discussion of the engineering status of the Waldo Waterman ship followed Mr. Geisse's address as well as of other aeroplanes and modifications of automobile engines now contemplated for adaptation to private commercial aeroplanes.

In closing the meeting, C. H. Baxley, in charge of student activity, announced that the Metropolitan Section would award prizes to students presenting outstanding papers on automotive and aeronautical subjects during the coming year. These prizes will be $50 first prize; $25 second prize, and three prizes of $10 each.

Through the courtesy of the Pan American Airways, a talking picture entitled "Flying the Lindbergh Trail" was presented. These pictures showed clearly the many engineering problems facing the aeronautical engineers in the design of large transport aeroplanes for long distance flights.

Many prominent men of the aviation world were present including E. P. Warner, Ralph P. Upson, Howard T. Ailor, Dean Barker of Columbia University, Dean Seville of New York University and Dr. Davis of the Stevens Institute of Technology.

Dennis Advocates Car Inspection

● **Northwest**

The opening meeting of the 1935-36 season of the Northwest Section, held Sept. 20 at the Mayflower Hotel, Seattle, was kept in tune with National Safety Week by Fred L. Dennis, director of highway safety, Bendix Products Corp., who presented his paper, "How We May Make Our Highways More Safe." Col. Dennis was introduced to the more than 50 members and guests by Police Chief W. B. Kirtley of Seattle. Thirty-nine attended the dinner before the meeting.

The speaker presented startling statistics in showing the need for municipal stations for testing motor-vehicles and for laws with "a lot of shark's teeth" to rule unsafe vehicles from the road.

In the discussion, engineering of highways and the physical fitness of drivers were brought out as additional safety elements.

James H. Frink, chairman of the Section, presided. Howard A. Reinhart organized the meeting as chairman of the programs committee.

The guests included H. W. Drake, secretary the past-chairman of the Oregon Section; Chief W. Cole of the Washington State Patrol; J. M. Bollong, traffic engineer of the City of Seattle; and D. A. Shelor, manager of the Automobile Club of Washington.

Meeting Takes On Military Aspect

● **Indiana**

With A. W. Herrington, president, Marmon-Herrington Co., speaking on "Late Developments in Military Combat Vehicles and Tanks", the opening meeting of the Indiana Section at the Indianapolis Athenaeum, October 17, had a decided military bearing. Among the 189 who heard Mr. Herrington speak were prominent army men including Col. Geo. V. Strong, Commanding Officer 11th Infantry; Major Wm. H. Craig, Adjutant, 11th Infantry; Capt. William B. Earle, 11th Infantry and Post Adjutant, and Lieut. Paul R. Walters, Assistant Post Adjutant. A group from the Officers Reserve Corps and from the Indiana National Guard also were present.

Mr. Herrington described the four classes of military combat vehicles, and their special fields; scout and reconnaissance, light and heavy types of tanks, and the subdivisions of wheeled and track laying vehicles. He believes that both track and wheeled combat vehicles have particular uses and advantages. One newer trend in wheeled combat vehicles is the provision of steering from both ends, offsetting their turning limitations in comparison with track laying types.

Mr. Herrington seriously questions the rumored 45 m.p.h. ranges of tanks over rough terrain. He stated that while such vehicles might be designed, he doubted the ability of human beings to stand the gaff of being thrown around at such speeds. The pictures illustrating the talk convinced those present

that 20 m.p.h. was about the maximum speed that humans could stand over rough country. The pictures shown included A.A.A. tests of the Marmon-Herrington Combat two-man tank in which the vehicle took four foot perpendicular drops, pitched up, over and down dykes and across trenches.

The pictures also showed a wheeled combat car, with a turret, capable of being driven from either end and through 36 in. of water and a two man combat tank with a turning radius of 8½ ft. and capable of passing through 36 in. of water with none of it entering the two man compartment.

Wooler Discusses Bearing Applications

● **Milwaukee**

Holding its first meeting under its new chairman, C. M. Eason, the Milwaukee Section met Oct. 7, at the Milwaukee Athletic Club. Following a dinner attended by 75 members and guests, Ernest Wooler, chief engineer, The Timken Roller Bearing Co., aided by his assistant, Robert M. Riblet, spoke to an audience of 106 on "Application of Anti-Friction Bearings in the Automotive Industry." The talk was illustrated by more than 50 lantern slides.

After briefly tracing the evolution of bearing design since the ball-bearing was originated in Europe 60 years ago, touching on the standardization work of the S.A.E., Mr. Wooler discussed the application of bearings at many points of the modern automobile. The speaker emphasized the increased efficiency brought about by the use of anti-friction bearings. An example used was that the old plain bearing steering gears had an efficiency of around 40 per cent whereas the modern anti-frictionized steering gears have an efficiency of around 80 per cent.

The Milwaukee Section has changed its meeting day to Monday this year to permit its "traveling" members to attend.

Piston Ring Papers Promote Discussion

● **Pittsburgh**

The Pittsburgh section meeting of Oct. 15 at Webster Hall was attended by more than 150 who heard Ralph R. Teetor and Macy O. Teetor discuss various phases of piston rings. At the dinner before the meeting Macy Teetor gave an impromptu performance on the electric organ. Other entertainment was provided by an 8-piece orchestra.

Chairman F. W. Heisley opened the meeting by outlining plans of the Section for the coming year. He then introduced Ralph Teetor, in charge of engineering, Perfect Circle Co. Mr. Teetor explained that many things which were problems when he addressed the Pittsburgh Section four years ago have now been solved. He stressed the work of the Society as important in the advancement of the industry.

In discussing piston rings the speaker explained that, simple though they seem, they are intricate in that there is practically no function of the engine that does not affect them in some way. Influence on the performance of rings can be traced to cylinders, pistons, connecting rods, crank shafts, lubricating systems, ignition systems, gas distribution systems and almost every other part of the engine.

Macy Teetor, in charge of experimental and research work of the Perfect Circle Co., showed slides illustrating recent research laboratory discoveries. In discussing oil consumption he stated that most attention on this subject has centered around piston and rings. He named scuffing as a present day plague, pointing out that an engine which scuffs is not economical in oil consumption. He explained that the difference between scuffing and scoring is that a scuffed assembly will smooth itself under operation whereas a scored assembly must be reconditioned.

Printed question cards facilitated answering a large number of questions without confusion and led to an interesting discussion in which B. H. Eaton, C. R. Noll, Murray M. Fahnestock, G. W. Brisbin, Ralph Baggaley, J. A. Harvey and others participated.

Section Participates in Aero Meeting

● **St. Louis**

The October meeting of the St. Louis Section has been postponed to enable the members to attend the 1935 National Technical Aeronautical Meeting, sponsored by the St. Louis Section of the American Society of Mechanical Engineers at the Chase Hotel, Oct. 10, 11 and 12.

Standards and Research on West-Coast Programs

The Standards and Research programs of the Society will be presented at the S.A.E. Pacific Regional Meeting and at three Pacific Coast Section meetings during the month of November by R. S. Burnett, manager, S.A.E. Standards department, and C. B. Veal, manager, Research department. At the Pacific Regional Meeting to be held at the Hotel Whitcomb, San Francisco, Nov. 18 and 19, Mr. Veal will review the work of his department under the title "Cooperation the Keystone of S.A.E. Research" emphasizing as his title indicates the importance of cooperative human effort in even the most technical aspects of automotive research. Mr. Burnett's title will be "The Standards Road to Profits" which covers a look at the past, present and future of the S.A.E. standardization activities.

Other aspects of Standards and Research work will be presented at Section meetings in Los Angeles on Nov. 15, Portland on Nov. 21 and Seattle on Nov. 22, according to the schedule established at the time the S.A.E. JOURNAL went to press. Pacific Coast Section members will, of course, receive the usual notices from their Section officers with confirmation of dates.

Perfect Car Visioned in Research Talk

● **Buffalo**

Before an audience of 200 members and guests of the Buffalo Section gathered at the Hotel Statler on the evening of Oct. 8, T. A. Boyd, head of fuels section, General Motors Research Division, outlined the requirements for developing a perfect automobile in his paper entitled, "Research in the Automobile Industry." The dinner preceding the meeting was attended by 70.

Pointing out that although in 1909 a boastful manufacturer pronounced his motor car "perfect," the speaker listed a number of things that are still to be accomplished before the development of a perfect automobile may be hoped for. Among these requirements he listed cheaper light metals, rust-proof irons and steels, better lubricants and better knowledge of what happens in the combustion chamber. Mr. Boyd explained that the motor cars of today are not the result of one invention nor scores of inventions, but of the utilization of all discoveries since fire was first used and the principle of the wheel utilized.

As there are 225 products contributing to the automotive industry, Mr. Boyd stated there is much research work to be done before each of these fields is fully developed. Defining the conservative as, "someone who never wants anything done for the the first time", he pointed out pioneers such as Ford, Packard, Duryea, Peugot and Olds were, fortunately, not conservatives.

Mayo and Price Give Diesel Papers

● **No. California**

Diesel engines was the subject of the Oct. 8 meeting of the Northern California Section at the Athens Athletic Club, Oakland. Roy E. Mayo, service engineer of the Caterpillar Tractor Co., spoke on "Interesting Phases of Diesel Fuel-Ignition Equipment." He was followed by Nathan C. Price, research engineer, whose paper was "Past and Present Developments in Single-Valve Diesel Engines." Both speakers used charts to illustrate their papers. Charles A. Winslow and J. R. MacGregor gave prepared discussions.

The meeting was attended by 187, following a dinner at which 67 were present.

● **So. California**

Ball players of the Southern California Section resting between innings at the Sept. 21 outing when 22 members and friends were guests of the Arden Dairy

Taub and Norris Address Students

● **Detroit**

The Student Activity of the Detroit Section stole a march on the oldsters by staging a bang-up meeting on October 14, a full week before the first regular fall meeting of the Section. Over 300 were present, including students and faculty members of the Detroit Institute of Technology, General Motors Tech, Lawrence Institute, Michigan State College, University of Detroit, and University of Michigan, besides many senior members of the Society.

The excellent program arranged by R. N. Janeway and his committee on Student Activities was responsible for the large attendance. Alex Taub, research engineer, Chevrolet Motor Co., led off with a fine inspirational talk, "Is There a Santa Claus?" Curiosity as to what this old gentleman might have to do with the automotive industry brought many a skeptic out. The gist of Mr. Taub's remarks was that luck, or "Santa Claus", plays a tremendous part in shaping men's careers. He then went on to show that a young man must have much ability to be able to take advantage of the golden opportunity when it arrives.

He stressed usual qualities of character, personality and training, but indicated that it is necessary to impress the right person with these qualifications. This individual may be a large size "brass hat", or just a "crack pot". How the big boss arrived at his job—through production, finance or accounting—will vary his viewpoint and judgment. "Finishative"—the ability to finish a job once started—he rated higher than initiative. The chap with the proverbial "ants in his pants" may start many things, but the clean-up man will get the glory.

Other sound advice followed, too voluminous to relate here. R. F. Norris, acoustical engineer, Burgess Battery Co., touched on the lighter side of life as he regaled the boys with wisecracks that wound through the general theme of automobile acoustics. His history of the development of noise in cars was a masterpiece of humor, if not of engineering. In a more serious moment, he went into the intricacies of the decibel, that rubber yardstick of noise, and demonstrated with sound apparatus.

Engineer's Role Vital in Transport Progress

● **Philadelphia**

William B. Stout, president, Stout Engineering Laboratories, and of the Society of Automotive Engineers, and John A. C. Warner, secretary and general manager of the Society, combined to make the opening meeting of the Philadelphia Section on Oct. 9 an outstanding success.

Both Mr. Stout and Mr. Warner discussed the major role that automotive engineering has played in the development of transportation and of civilization.

In discussing the Scarab car, Mr. Stout said that it was not streamlined and that a land vehicle could not be streamlined. Moreover, he declared that at automobile speeds, power required to overcome head resistance was not important. Consequently, he stated that the only consideration that had been given to aerodynamics in the design of the car was to provide for stability in cross winds.

Both Mr. Stout and Mr. Warner illustrated their talks with slides and motion pictures.

Commenting on the report of Section Treasurer Robertson, Mr. Warner said that the Society had ended its fiscal year on Sept. 30 very comfortably in the black on a national basis. He also announced that the Council, expecting a continued improvement in business, has mapped out plans for an ambitious program of activity next year.

The meeting was attended by more than 100.

S.A.E. Engineering Relations Committee

Three members of the S.A.E. Engineering Relations Committee, which was provided for by the Council, at its meeting of June 16, to coordinate S.A.E. national and sectional activities in regulatory and legislative matters, have been appointed and approved by the Council. W. J. Davidson will serve as Chairman for one year, T. L. Preble has been appointed to serve two years and David Beecroft to serve three years. The other two members of this Committee are the Chairman of the Research Committee and the Chairman of the Standards Committee, ex-officio, Ralph R. Teetor and C. W. Spicer, respectively.

Engineering Future Portrayed by Stout

● **Baltimore**

William B. Stout, president of the Society, and John A. C. Warner, secretary and general manager, addressed 185 members and guests of the Baltimore Section at its meeting in the Brockway Building on Oct. 8. Ninety attended the dinner before the meeting.

Mr. Stout in his address, "Where Do We Go From Here", outlined the progress that has been made in transportation and the vital part that research will play in further advances.

"Conquering the World with Automotive Engineering" was the subject of Mr. Warner's talk. He said that the Society has members in 35 countries on every continent and pointed to many accomplishments of automotive engineers in different parts of the world.

Both talks were illustrated with colored and other motion pictures.

Bonta Analyses Steering Geometry

● **So. California**

The Southern California Section, at its meeting of Oct. 11, at the Mona Lisa Restaurant in Los Angeles, heard Frank N. Bonta deliver his paper, "An Analysis of Automobile Steering Geometry." Seventy-five were present at the dinner and 15 others came in later for the meeting and paper.

In his talk, which he purposely limited to an elemental analysis of the underlying principles involved in the steering alignment problem, Mr. Bonta made frequent references to diagrams and charts. He particularly stressed that, from the point of view of safety and economy, both service men and operators should have a fundamental knowledge of the steering geometry of an automobile.

Following Mr. Bonta's talk a general discussion took place in which E. E. Tattersfield, William Brown, G. A. Collender, E. Favary and W. E. Powelson participated.

Oregon Student Branch Holds First Meeting

● **Oregon**

The newly organized Student Branch of the Oregon Section assembled in the engineering laboratory of the Oregon State College on Oct. 3, for its first meeting. An interested group of 40 students, faculty members and guests were addressed by J. Verne Savage, chairman, Oregon Section, who outlined the benefits and the coming events of the newly organized student branch.

Harley W. Drake, secretary, talked on "Safety in Industry," stressing the opportunities in the field of safety engineering. Following Mr. Drake's talk the Student Branch decided to inaugurate a safety program on the campus of the Oregon State College to promote more careful driving.

Diesel Meeting Has Record Attendance

● **New England**

A record attendance of 450 members and guests of the New England Section gathered at Walker Memorial, Massachusetts Institute of Technology, on October 8, to hear two papers on Diesels.

O. D. Treiber, manager and chief engineer, Diesel Division, Hercules Motors Corp., was the first speaker. He was followed by Myron S. Huckle who read a paper prepared by T. R. Kelly, Diesel field engineer, Waukesha Motor Co. Mr. Kelly was, unfortunately, called away before the meeting.

Dinner was served to 66 earlier in the evening.

Warner Addresses Toronto Meeting

● **Canadian**

The largest dinner attendance in its history marked the Oct. 16 meeting of the Canadian Section held in the Concert Hall of the Royal York Hotel, Toronto. A group of 60 students of the Faculty of Applied Science and Engineering were guests of the Section.

John A. C. Warner, general manager of the Society, represented President William B. Stout, whose scheduled attendance was prevented by illness, by presenting Mr. Stout's address, "Where Do We Go From Here?" This was illustrated by motion pictures graphically revealing contributions made by Mr. Stout toward the evolution of transportation by road, rail and aircraft.

Following the meeting Mr. Warner was the guest of honor at a buffet supper at the home of the Section Secretary, W. B. Hastings, attended by officers and past officers of the Canadian Section.

Discusses Fuels for Tomorrow's Engines

● **Cleveland**

Earl Bartholomew, director of research, Ethyl Gasoline Corp., talked on "Fuels for Today's and Tomorrow's Engines" before 79 members and guests of the Cleveland Section at the Cleveland Club Ballroom on Oct. 14.

The dinner preceding the meeting was attended by a group of 56. Entertainment was provided.

(Continued on page 29)

"The S.A.E. Is A Forum"

SAYS

THIS PAGE IS PRINTED FOR THE INSPIRATION OF OUR PRESENT MEMBERS—FOR PRESENTATION TO PROSPECTIVE MEMBERS

Harry L. Horning, President, Waukesha Motor Co.

"THE Society is a forum where men are appreciative of the benefits available through personal contacts with the best minds who invariably are in a most communicative mood on the subject in which they excel.

"You are always meeting men in the Society of Automotive Engineers who know more than you do. It is thus up to the man himself, provided he is open-minded, if he is to attain success under these favorable circumstances of membership."

Harry L. Horning is president of the Waukesha Motor Co. and a Past-President of the S.A.E. For many years he has contributed generously of his time and efforts to the furtherance of S.A.E. activities. His point of view is that of an executive in an important branch of the automotive industry.

What Members Are Doing

Major M. V. Brunson, Quartermaster Corps, U. S. Army, formerly located at Fort McPherson, Ga., has been transferred to Fort Leavenworth, Kansas, at which station he is enrolled as a student officer at the Command and General Staff School.

George L. McCain, formerly research engineer, Chrysler Corp., Detroit, is now chief

George L. McCain
Joins Air Temp

development engineer of the Air Temp Div., of the Chrysler Corp.

Edward I. Rusk is in the engineering department of the Auto-Lite Co., Syracuse, N. Y.

Joseph R. Akerman has joined the Phoenix Oil Co., Augusta, Georgia, as engineer. Formerly he was an instructor at the Georgia School of Technology, Atlanta, Ga.

Joseph L. Wyborny has been named sales manager, The House of Gurney, Inc., Yankton, S. D. He was formerly manager of the petroleum department.

Capt. Samuel Vance Krauthoff, motor maintenance officer, U. S. Army, Fort Knox, Ky., has been transferred from the 19th Field Artillery to the 68th Field Artillery.

George D. Evans has joined the Ann Arbor Municipal Airport, Ann Arbor, Mich., as supervising engineer. He was formerly a member of the engineering staff of the Hammond Aircraft Corp., Ypsilanti, Mich.

Karl H. Effmann, is now junior engineer, U. S. Engineer Office, (War Department), Los Angeles, Calif. He was formerly territorial representative, Perfect Circle Co., Hagerstown, Ind.

Lyle G. Ecker, formerly engineer, United Parts Manufacturing Co., Chicago, Ill., is now engineer, Perfection Auto Parts Manufacturing Corp., Chicago.

Gordon M. Guilbert has been appointed vice-president of the Twin Disc Clutch Co. of Racine, Wis. He was formerly sales manager for the same company.

Arthur Bordeaux Nicholson has been promoted from 1st Lieutenant, to Captain of the Coast Artillery Corps, U. S. Army, Fort MacArthur, San Pedro, Calif.

Leonard B. Gilbert has been appointed sales manager in the Chicago territory of the White Co. Prior to this appointment he had been national account salesman for the above company.

J. Howard Pile, formerly editor of Chek-Chart Corp., Chicago, has been promoted to vice-president and editorial director of the corporation.

Judson A. Purvis, formerly managing editor, is now editor of Chek-Chart.

Karl Knohl, formerly designer, Winton Engine Corp., Cleveland, is now engine designer, S. R. Dresser Manufacturing Co., Bradford, Pa.

David Benjamin, who was vice-president of the Gabriel Co. of Cleveland, is now secretary-treasurer of the Pressure Castings, Inc., Cleveland.

Frederick Klein, formerly research engineer of Sipp-Eastwood Corp., Paterson, N. J., has been appointed chief engineer of the same company.

Nelson G. Kling, formerly designer, Eclipse Aviation Corp., East Orange, N. J., is now designer, Fairchild Aerial Camera Corp., Woodside, N. Y.

George H. Mosel, formerly Pacific Coast manager for the Raybestos Division of Raybestos-Manhattan, Inc., has been named general manager of the Robison Air Jack Co., San Francisco.

George H. Mosel
Takes New Post

Mr. Mosel is a past-chairman of the Northern California Section of the Society, and will continue to be active in the Section.

Edgard C. DeSmet has resigned as body designer, Hudson Motor Car Co., Detroit.

Joseph A. Doyle is now automotive engineer, The Pure Oil Co., Chicago. He was formerly branch manager for the Bendix Stromberg Carburetor Co., Chicago.

We Add Persia To Our Mailing List

To the roll of countries overseas in which the Society numbers members—in the section of the index now reading Palestine, Peru, Philippine Islands, Poland, Puerto Rico—can be added Persia—or Iran as it is spelled officially. Lieut. Habib Naficy of the engineer corps, Imperial Iranian Army, is the new member of the Society whose inclusion makes this possible.

After a period as inspector of contracts, assigned to the Marmon-Herrington Co., Indianapolis, Lieutenant Naficy has been ordered to join the military commission at Berne, Switzerland, of the Imperial Iranian Legation.

Paul E. Hemke, formerly associate professor, department of mechanics, Case School of Applied Science, Cleveland, is now head of the aeronautical engineering department, Rensselaer Polytechnic Institute, Troy, N. Y.

Frank E. Queeney has recently become field engineer for the Electro-Motive Corp., La Grange, Ill. Formerly he was representative, resident inspector, for the same company in Cleveland.

Joseph H. Appleton, formerly chief engineer, Hall Manufacturing Co., Toledo, Ohio, is now affiliated with Joseph H. Appleton & Son, Mechanical Engineers, Huntington Park, Calif.

A. M. Yocom is now connected in Detroit with the Raybestos-Manhattan, Inc. He was formerly chief engineer, Multibestos Co., Cambridge, Mass.

D. H. Pulleyblank, formerly with the Hurricane Aviation Corp., Detroit, is now with the Ex-Cell-O Aircraft & Tool Corp., Detroit, in the testing-experimental laboratory.

Ralph C. Chesnutt, experimental engineer, Cleveland Tractor Co., was the author of a paper on "The Principles of Diesel Engines" at the Diesel Power Conference recently held at the Iowa State College.

Helmer G. Christenson, formerly district manager for the National Battery Co. and the Gould Storage Battery Co. in Detroit, has joined United Motors Service.

R. M. Schaefer, formerly mechanical engineer at the Waukesha Motor Co., Waukesha, Wis., is now with the Twin Disc Clutch Co., Racine, Wis.

Charles A. Morss is now inspector, Pratt & Whitney Aircraft Co., East Hartford, Conn.

H. E. Andersen who was connected with the Pontiac Motor Co., dynamometer laboratory, Pontiac, Mich., is now regional supervisor motor equipment, western region, of the Sun Oil Co., Detroit.

Paul Weeks
Heads Special Sales

Paul Weeks, who was Washington, D. C., manager of the Caterpillar Tractor Co., Peoria, Ill., is now manager of the special sales division.

Robert S. Craig has joined Brewer and Le Blanc, Inc., Jersey City, N. J., as a salesman.

Charles S. Draper, formerly research associate, Massachusetts Institute of Technology, Cambridge, Mass., is now assistant professor.

Walter J. Baumgartner, formerly assistant to Mr. Bock, Truck and Trailer Engineering Division, General Motors Truck Corp., Pontiac, Mich., is now assistant truck engineer of the above company.

James Lynah, whose name was associated for many years with the development and manufacture of special fabrics used in the automotive industry, has emerged from retirement to become director of physical education and athletics for his alma mater, Cornell University.

Stanley W. Otto, formerly superintendent, Melling Forging Co., Lansing, Mich., is now factory manager, Lindell Drop Forge Co., Lansing, Mich.

L. G. Knapp has severed his connection with Montgomery Ward, Chicago, Ill.

Charles W. Almstead is now connected with the Columbia Axle Co. of Cleveland, Ford Two-Speed Axle Division, as sales representative. He was formerly European representative for the Warner Electric Brake Corp., Beloit, Wis.

Edwin A. Ross is now professor of aeronautics, San Diego State College, San Diego, Calif., he was formerly head of the industrial department, Taft Junior College, Taft, Calif.

J. Russell Walsh has been assigned to reserve duty, Corps Area Motor Repair Shop, Schenectady, N. Y.

Eugene Laas, formerly mechanic, Theodore Luce, New York, is now a draftsman in the Materials Testing Division, Works Progress Administration, New York.

Chris J. Fields, formerly layout man, Body Engineering Works, Hayes Body Corp., Grand Rapids, Mich., is body layout man, International Harvester Co., Fort Wayne, Ind.

Frank B. Sexton is now manager, Marine Division, U.S.L. Battery Corp., New York. He was formerly president, F. Benjamin Sexton Corp., New York.

Jack Hughes, formerly fleet service instructor, Chevrolet Motor Co., Detroit, is now owner of the Jack Hughes Chevrolet Co. at Van, Texas.

Fred W. Cederleaf is no longer connected with General Motors of Canada as standards manager.

Christian C. Bowman is now president, Checker Moving and Storage Co., Detroit, Mich. He was formerly with the Standard Motor Truck Co., Detroit, as chief engineer and sales manager.

Fred C. Booth has joined the Arma Engineering Co., Brooklyn, N. Y., as designer. He was formerly design engineer for F. E. Lonas, New York, N. Y.

William B. Wheatley, chief test pilot, Consolidated Aircraft Corp., has been transferred to Lindbergh Field, San Diego, Calif.

W. H. Welch is now in the automotive engineering department, Standard Oil Co. (Indiana).

Frank A. Quackenbush, formerly division superintendent, Interstate Transit Lines, Chicago, is now sales engineer, bus division, Kenworth Motor Truck Corp., Seattle, Wash.

Sydney A. Currin, formerly technical representative, Clayton Dewandre Co., Ltd., Lincolnshire, England, is now connected with the Simms Motor Units, Ltd., London, as sales director.

V. W. Kliesrath
Attends Foreign Shows

Victor W. Kliesrath, director of automotive engineering of the Bendix Aviation Corp., went to Europe to attend the Paris, Brussels and London Motor Shows.

Arthur E. Felt has enrolled in the Graduate School of the University of Michigan to continue his studies in automotive engineering. He was formerly with the Henderson Produce Co., Laclede, Mo., as dock foreman.

Edward J. McLaughlin is junior engineer dynamometer laboratory, Standard Oil Co. of Calif., Richmond, Calif.

Walter H. Morris has joined the Babcock & Wilcox Co. of Barberton, Ohio, as a student engineer in the drafting department.

Earl C. Rieger is now maintenance engineer of the International Harvester Co., Chicago. He was formerly laboratory engineer for the same company.

William C. Oberg, formerly manager, sales engineering, Carnegie Steel Co., Pittsburgh, Pa., is now manager of operations, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

George W. Wright

The Society has just been informed of the death of *George W. Wright,* late superintendent of the garage department of the Toronto Transportation Commission.

After serving as engineer on Toronto railway valuation work, Mr. Wright joined the staff of the Toronto Transportation Commission in 1921. During heavy construction and rehabilitation work of the commission's early operation he was engineer, in charge of construction materials.

Appointed superintendent of the T.T.C. garage department in 1930, he became an associate member of the Society in 1931 and took an active part in the Canadian Section's work.

Brake Liners Elect

The Brake Lining Manufacturers' Association at its annual meeting, in New York, elected the following officers: President, *G. M. Williams,* president, Russell Manufacturing Co.; second vice-president, *H. A. Gillies,* vice-president, American Brakeblok Corp.; Members of the executive committee elected were: *T. L. Gatke,* president, Gatke Corp.; *M. F. Judd,* general manager, Raybestos Div. of Raybestos-Manhattan, Inc.; *W. C. Dodge, Jr.* of Keasbey-Mattison Co.

Parker Visits Headquarters

A recent visitor to S.A.E. headquarters was *Philip S. Parker,* works manager, Airzone Ltd., Sydney, Australia. Mr. Parker who had been spending several months in the United States studying radio developments, expressed interest in the possibility of S.A.E. members in Australia (of which there are nearly 50) getting together in some sort of informal group meetings.

News of the Society

(Continued from page 26)

Committee Appointments

Among the appointments to committees recently approved by the Council are included:

Appointment of G. A. Round to the Ordnance Advisory Committee; in the Lubricants Division, Standards Committee, appointment of D. G. Proudfoot to replace F. E. Holsten and F. F. Kishline to replace L. Thoms. Mr. Proudfoot is to represent the Western Petroleum Refiners Association.

Lauer Predicts Safe Driving

● Pittsburgh

"America is to be a safer place to drive in."

The Pittsburgh Section meeting of Sept. 13 was held in conjunction with the Western Pennsylvania Safety Council at a luncheon in the Chamber of Commerce Auditorium. Dr. A. R. Lauer, associate professor of psychology of Iowa State College, gave an interesting paper on elements of safe driving, illustrated by motion pictures.

Dr. Lauer predicted that in the future scientists, empowered by a national law, will determine whether a person is physically or mentally fit to operate a motor vehicle and that children in school will be taught how to drive an automobile safely. The author bases this prediction on the fact that science is now determining the factors responsible for traffic accidents and evaluating the results of its research to set up standard tests for drivers as a means of cutting down America's annual automobile toll of 40,000 dead and 1,000,000 injured. Motion pictures of tests conducted were shown. By means of these tests and the incorporation in the schools' curriculum of the subjects of automotive mechanics and car operation, Dr. Lauer believes the highways of the future can be made safer.

Causes of accidents, it was stated, fall into four classes: vehicle, roadway, external conditions (weather), and driving, the last being responsible for most accidents.

Drivers were said to fall into three classes: 75 per cent in the accident-free group, 20 per cent in the accident-prone group, and 5 per cent in the accident-liable group.

The accident-free group represent average drivers who are not likely to cause an accident. The accident-prone group are those who have had one crash and apt to be responsible for another. The accident-liable group are those whose physical or mental condition makes them a menace to traffic.

Dr. Lauer, in the interest of traffic safety, advised employers to transfer men distracted by financial or domestic worries to jobs other than driving, until they have recovered a normal emotional balance.

It was also stated that radios in cars distract some drivers, but do not interfere with the safe driving of others.

New Members Qualified

These applicants who have qualified for admission to the Society have been welcomed into membership between Sept. 10, 1935, and Oct. 10, 1935.

The various grades of membership are indicated by: (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate Member; (SM) Service Member; (FM) Foreign Member.

BROMAN, KENNETH G. (A) Detroit representative, Matthews Mfg. Co., Worcester, Mass.; (mail) 1421 Delaware Avenue, Detroit.

CAMPBELL, GEORGE J. (A) sales engineer, Johns-Manville Corp., 22 East 40th Street, New York City.

CANTELON, W. H. (A) manager, Auto Specialties Mfg. Co., Windsor, Ontario, Canada.

CAPWELL, BENJAMIN F. (A) district lubrication manager, Socony-Vacuum Oil Co., Inc., 230 Park Avenue, New York City; (mail) 139-16 86th Avenue, Jamaica, L. I., N. Y.

COLLETT, KNUT (FM) director, Moller & Larsen A/S, Danmarksgate 52, Oslo, Norway.

DOERR, MAXWELL H. (J) Reo Motor Car Co., Service Department, Lansing, Mich.

FRANKENFIELD, TITUS EMERSON (J) engineer, Schwitzer-Cummins Co., 1125 Mass Avenue, Indianapolis.

GORDON, DWIGHT M. (J) experimental engineer, Carter Carburetor Corp., 2838 North Spring Avenue, St. Louis, Mo.

GUEST, TOM (A) proprietor, First Avenue at 25th Street, Saskatoon, Saskatchewan, Canada.

HOLAN, JAMES (M) president, American Coach & Body Co., 3809-15 Clark Avenue, Cleveland.

LASSEN, NIELS (FM) chief engineer, M. O. Schovens Bilcentraler A/S, Oslo, Norway.

MIDDLETON, LESLIE HAMILTON (M) executive engineer, Electric Auto-Lite Co., Toledo, Ohio.

MOIR, HARRY L. (J) laboratory engineer, Pure Oil Co., 35 East Wacker Drive, Chicago; (mail) 7623 Greenview Avenue.

NELSON, GUSTIN MACALLISTER, CAPT. (SM) instructor, Infantry School, 66th Infantry (Light Tanks), Fort Benning, Ga.

NEVATT, MAJOR C. G., O.B.E. (FM) works manager, Bristol Tramway & Carriage Co., Ltd., Brislington, Bristol 4, England; (mail) The Haven, Waterford Road, Henleaze, Bristol, England.

PEREZ, RAUL (M) engineer, Standard Oil Co. of Cuba, P. O. Box 1303, Havana, Cuba.

ROBINSON, ANDREW (FM) owner, W. Robinson & Son, Lismore, N. S. W., Australia; (mail) Box 15A, Post Office.

RODGER, JAMES SCOTT (A) instructor, Department of Education, Victoria, B. C., Canada; (mail) 2138 Charles Street, Vancouver, B. C., Canada.

RUTSCHOW, FREDERICK H. C. (A) mechanic, Slaughter, Russell Co., 225 Montgomery, San Francisco; (mail) Box 67, Burlingame, Calif.

SCARAMUZZO, LOUIS A. (A) mechanic, Tompkins Bus Corp., 735 Richmond Road, Staten Island, N. Y.; (mail) 2700 Amboy Road, New Dorp, S. I., N. Y.

SCHEBLER, FRANK J. (A) engineer, New York Telephone Co., 140 West Street, New York City; (mail) 1860 Willoughby Avenue, Brooklyn, N. Y.

SCHNEE, VERNON H. (M) industrial research, Battelle Memorial Institute, Columbus, Ohio; (mail) 505 King Avenue.

SMALLMAN, FRANK E. (J) Mahwah, N. J.

STEWART, FRANK G. (A) president, Standard Automotive Supply Co., Inc., City of Washington; (mail) 1800 14th Street, North West.

WHITESELL, FRANK E. (A) sales manager, automotive lubrication, Socony-Vacuum Oil Co., Inc., 26 Broadway, New York City.

YAMAMOTO TAKAAKI (FM) engine designer, Mitsubishi Jukogyo Kaisha, Oemachi, Nagoya, Japan; (mail) care of Mitsubishi Shoji Kaisha, Ltd., 120 Broadway, New York City.

Applications Received

The applications for membership received between Sept. 15, 1935, and Oct. 15, 1935, are listed herewith. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABRAMS, MORRIS, 1422 Lincoln Place, Brooklyn, N. Y.

BATES, CURTIS L., professor, Lawrence Institute of Technology, Highland Park, Mich.

BEARD, RALPH H., supervisor of repairs, New York Telephone Co., New York City.

BEUSCH, CHRISTIAN, consulting engineer, Wäudenswil, Switzerland.

BILLINGS, EDWIN C., sales engineer, Twin-Disc Clutch Co., Racine, Wis.

BRIDGEMAN, EDWARD F., service manager, Ford Motor Co., New York City.

BROOKS, CLAUDE J., district lubrication engineer, Associated Oil Co., Los Angeles, Cal.

BROWN, KENNETH M., test engineer, Shell Oil Co., Martinez, Cal.

BROWN, W. W., owner and manager, W. W. Brown Machine Works, Kansas City, Mo.

CERU, PAUL VICTOR, draftsman, O & S Bearing Co., Detroit.

CHAMBERLIN, WILLIAM G., editor, Chexall Division, The Chek-Chart Corp., Chicago.

CREIGHTON, ALLAN, experimental and research department, Waukesha Motor Co., Waukesha, Wis.

DAILEY, FLETCHER LEBARON BOWEN, manager of garage, Straights Super Service, Providence, R. I.

EVANS, ROBERT B., vice-president and general manager, E. S. Evans & Sons, Detroit.

FRAME, D. E., superintendent of equipment, Delaware Electric Power Co., Wilmington, Del.

GALDO, FRANCIS, designer, International Harvester Co., Fort Wayne, Ind.

GERDAN, DIMITRIUS, dynamometer assistant, Chevrolet Experimental Laboratory, Detroit.

GIESEKE, WILBUR I., automotive engineer, 1632 Don Carlos Avenue, Glendale, Cal.

GOODALE, R. WAYNE, research engineer, Standard Oil Co. of California, Richmond, Cal.

GRIBBIE, JACK M., sales manager, Shakeproof Lock Washer Co., Chicago.

GUTMAN, JOSEPH J., president, Diesel Motor Sales and Service Corp., Los Angeles, Cal.

JACKSON, LAWRENCE B., manager of engineering, Fairbanks Morse & Co., Beloit, Wis.

KLEY, HOWARD F., research engineer, Shell Oil Co., Martinez, Cal.

LATHAM, ROBERT H., JR., National Reemployment Service, California, Mo.

LAUFER, AL HARRY, sales engineer, J. Brunton Sons Co., San Francisco, Cal.

LEVY, MONROE, president, Alicino and Levy, Inc., New York City.

LIALIN, V. N., passenger cars and trucks, Stalin Automobile Plant "ZIS," Moscow, U. S. S. R.

MALAN, DANIEL FRANCOIS, lecturer, demonstrator, Atlantic Refining Co. of Africa, Ltd., Johannesburg, S. A.

MANNEY, CHARLES JOSEPH, engineer, The Seagrave Corp., Columbus, Ohio.

MARSHALL, JOHN THOMPSON, engineer, Eclipse Aviation Corp., East Orange, N. J.

MAYNARD, CHARLES WAYNE, mechanic, J. F. Long Co., Alameda, Cal.

MCLAUGHLIN, EDWIN J., junior engineer, Standard Oil Co. of Cal., Richmond, Cal.

MITCHELL, NORMAN, engineer, The Asiatic Petroleum Co., London, E. C. 3, England.

MUELLER, HENRY T., mechanical engineer, Ethyl Gasoline Corp., Experimental Laboratory, Detroit.

NAFICY, HABIB, FIRST LIEUTENANT, engineer, Imperial Iranian Legation, Berne, Switzerland.

PEDERSEN, TAGO VIGGO, designing engineer, Fairbanks Morse & Co., Beloit, Wis.

PETTER, WILLIAM EDWARD WILLOUGHBY, technical director, Westland Aircraft, Ltd., Yeovil, England.

PHELPS, CHARLES WORTHINGTON, instructor in engineering, Connecticut State College, Storrs, Conn.

PRIEST, HARRY T., secretary, P. K. Priest, Inc., Duluth, Minn.

RIGHTER, IRVING S., transportation supervisor, New Jersey State Police, Trenton, N. J.

SMART, HERCULES, vice-president and general manager, Canada Illinois Tools, Ltd., Toronto, Ont., Canada.

SORENSEN, LOU C., president, Turco Products, Inc., Los Angeles, Cal.

STEDMAN, FRANCIS H., chemical engineer, Standard Oil Development Co., Elizabeth, N. J.

VICKERY, HERBERT ANDREWS, works engineer, Dunlop Rim & Wheel Co., Ltd., Foleshill, Coventry, England.

VITELLO, GEORGE, owner, Combined Motor Truck Repair Co., Inc., New York City.

WHEATON, ELMER W., assistant manager, A. W. Wheaton Brass Works, Newark, N. J.

YOSHIDA, INAO, engineer, Sumitomo Steel Tube & Copper Works, Osaka, Japan.

Papers Available in Mimeographed Form

UNTIL current supplies are exhausted, copies of the papers listed are available in mimeographed form at a cost of 25 cents per copy to members; and at 50 cents per copy to non-members. Orders should specify the name of the author as well as the title of the paper desired.

Orders must be accompanied by remittance and should be addressed to Sessions Secretary, Society of Automotive Engineers, 29 West 39th St., New York, N. Y.

Alden, C. R.
Design and Development of Injection Apparatus for High Speed Diesels

Allee, H. D.
Quill Bearings—Past, Present and Future

Altman, Peter
Sales and Technical Problems of Private Commercial Airplanes

Anderson, R. J.
Machineability, Engineering Properties and Applications of Electric Furnace Cast Iron

Ballard, J. H., and Moore, N. A.
How the Design of Some Motor Parts Can Influence Piston Ring Performance

Ballard, J. H., Nixon, S., and Moore, N. A.
Piston Rings: Factors Contributing To Their Normal and Abnormal Wear

Becker, C. F.
Factors Affecting Gasoline Consumption in Automotive Vehicles

Blanchard, H. F.
A Discussion of 1935 Cars

Bull, A. W.
Rubber and Its Uses in Transportation

Burwell, A. W. and Camelford, J. A.
A New Idea in Lubrication

Camp, R. H.
The Supercharger

Cosford, E. J.
Outlook for High-Speed Diesel-Engine Application to Road Transport Vehicles

Creson, W. K.
Steering Safely

Croll, P. R., and DuBey, L. E.
How to Finish a Truck

De Forest, A. V.
Surface Integrity and Dynamic Strength

DeJuhasz, K. J.
Analysis of Surges in Fuel Injection Pipes

DeSmet, E. C.
The Practical Side of Planography

Dick, Burns
Hydraulic Brake Actuation

Dunbar, H. W.
1934 Developments in Cam and Cylindrical Grinding

Elden, H. E.
The Properties of Cellular Rubber for Passenger Car Cushions

Fassler, P. W.
Modern Resistance Welding in the Automobile Industry

Frehse, A. W.
Some Thoughts on Present Day Automobile Transmissions

Gebhardt, W. A.
A Study of the Efficiencies of Overdrive Units Used in Passenger Cars

Greene, C. F.
Aircraft Structural Design and Its Influence on Other Engineering Design

Hale, J. E.
When Is a Truck Tire Overloaded?

Holzapfel, G. L.
The Future of Butane as a Motor Fuel

Horine, M. C.
Motor Truck Transportation—Its Development and Future Possibilities

Hukill, H. D.
Vacuum Power Brakes

Jorgensen, C. H.
What Price Dynamite?

Kemper, Carlton, and Wood, D. H.
The N. A. C. A. Investigation of Cowling and Cooling of Radial Air-Cooled Engines

Larsen. A. E.
The Future of the Autogiro for the Private Flyer

Littlewood, William
Operating Requirements for Transport Airplanes

MacCoull, Neil, and Stanton, G. T.
Engine Knock Studied by Electro-Acoustical Instruments

Martland, R. W., Jr.
How Car Manufacturers Can Cooperate with the Commercial Fleet Operators

McLaughlin, E. J.
A Study of the Comparative Values of the Different Methods of Automotive Valve Reconditioning

McQuaid, H. W.
Some Factors Affecting the Performance of Tractor Gears

Merriman, M. E.
Bringing the Italian Sky Down to Earth

Nohavec, F. R.
Air Conditioning as Applied to Internal Combustion Engines

Oberfell, G. G., Alden, R. C. and Trimble, H. M.
The Trend of Volatility of Motor Fuels

Preble, T. L.
How to Buy a Truck

Preble, T. L.
Principles of Fleet Operation

Probst. K. K.
Transverse Leaf, Independent Springing

Reed, James
Our Accident Prevention Method

Reid, Elliott G.
Some Flying Problems

Sampson, P. J.
Valves for Internal Combustion Engines, and Their Related Parts

Scaife, A. J.
The Economical Loading and Operation of Motor Trucks

Schoenrock, O. R.
Recent Tractor Transmissions and Their Trend

Schumacher, Lieut. Comm. T. L.
Chemical Warfare

Sneed, John
Mechanical Mind Reading (Transmissions)

Spencer, D. P.
Development of Electric Cast Iron

Spring, F. S.
Are We Giving the Average Private Operator the Airplane Most Suitable to His Needs?

Spruance, F. P.
Rustproofing and Paint Adherence Technique

Wait, Louis
Aircraft Instruments and Their Uses

Weiger, J. A.
Resistance Welding in the Automotive Industry

West, C. L.
The Practical and Economic Application of Special Atmospheres in the Heat Treatment and Brazing of Metals

White, S. O., and Hedgeland, M. C.
Methods of Finishing Transmission Gears

Winchester, J. F.
Operation and Maintenance

Wise, W. F.
Single Point Boring of Cylinders and Diamond Turning of Pistons

Meetings Calendar

S.A.E. Annual Dinner

Nov. 4

Hotel Commodore, New York City

S. A. E. Annual Meeting

Jan. 13-17, 1936

Book-Cadillac Hotel, Detroit

S.A.E. Pacific Regional Meeting

Nov. 18 & 19

San Francisco, Calif.

(Under auspices of Pacific Coast Sections)

Baltimore—Nov. 7

Engineers Club; dinner 6:30 P. M. Subject—Maintenance.

Buffalo—Nov. 12

Hotel Statler; dinner 6:30 P. M. Precision Manufacture in Quantity Production—Thomas Barish, assistant chief engineer, Marlin-Rockwell Corp.

Canadian—Nov. 12 and Nov. 25

Nov. 12—Joint dinner with Canadian Automobile Chamber of Commerce; speaker, Hon. William D. Euler.

Nov. 25—Regional Meeting in Montreal.

Chicago—Nov. 18

Saddle & Sirloin Club, International Ampitheatre; dinner 6:30 P. M. Engineering Developments for 1936—Austin M. Wolf, automotive consultant.

Cleveland—Nov. 11

Cleveland Club; dinner 6:30 P. M. Diesel Engines—O. D. Treiber, chief engineer, Diesel Division, Hercules Motors Corp.

Dayton—Nov. 16

Engineers Club; dinner 6:30 P. M.

Detroit—Nov. 11

Book-Cadillac Hotel; Junior Student Activity Meeting 2:00 P. M.; dinner 6:30 P. M.; evening meeting 8:00 P. M. Speaker at evening session—C. E. Wilson, vice-president, General Motors Corp.

Indiana—Nov. 14

The Athenaeum, Indianapolis; dinner 6:30 P. M. The Modern X-Ray Science of Metals—Prof. G. L. Clark, University of Illinois. Welding and X-Ray Problems of the Production Man—R. Notvest, chief engineer, Welding Department, J. D. Adams Mfg. Co.

Metropolitan—Oct. 29 to Nov. 1

Regional Transportation and Maintenance Meeting; Hotel Robert Treat, Newark, N. J.

Milwaukee—Nov. 4

Design of Diesel Engines—Moyes J. Murphy, Murphy Diesel Co.

New England—Nov. 12

Walker Memorial, Massachusetts Institute of Technology, Cambridge; dinner 6:30 P. M. New Developments as Displayed at the New York Show—Dean A. Fales, associate professor, Massachusetts Institute of Technology. Review of Chicago Transportation Meeting—Francis I. Hardy.

Northern California—Nov. 18-19

Pacific Coast Regional Meeting; Hotel Whitcomb, San Francisco. Complete program printed elsewhere in this issue.

Oregon—Nov. 9 and Nov. 21

Nov. 9—Lloyds Golf Club House, Portland; dinner dance. A Trip to Mexico—L. Abbott, Southern Pacific Co. Nov. 21 Multnomah Hotel; Auto Show Dinner 6:30 P. M. Human Catalysis in S.A.E. Research—C. B. Veal, research manager, S.A.E. The House that Standards Built—R. S. Burnett, Standards Manager, S.A.E.

Philadelphia—Nov. 13

Convention Hall; dinner 6:30 P. M. Engineering Developments for 1936—Austin M. Wolf, automotive consultant.

Pittsburgh—Nov. 21

Webster Hotel; dinner 6:30 P. M., Cooling System Design.

St. Louis—Nov. 8

Coronada Hotel; dinner 6:30 P. M. Transportation and Maintenance Meeting.

Southern California—Nov. 15

Mona Lisa Restaurant, Los Angeles; dinner 6:30 P. M. Human Catalysis in S.A.E. Research—C. B. Veal, research manager, S.A.E. The House that Standards Built—R. S. Burnett, standards manager, S.A.E.

Syracuse—Nov. 11

Onondaga Hotel. Latest Developments in Air Transport—by a representative of Pan American Airways. There will also be descriptive moving pictures.

Washington—Nov. 11

University Club, Washington, D. C.; dinner 6:30 P. M. Subject—Safety Engineering.

In 37 of Today's New Models!

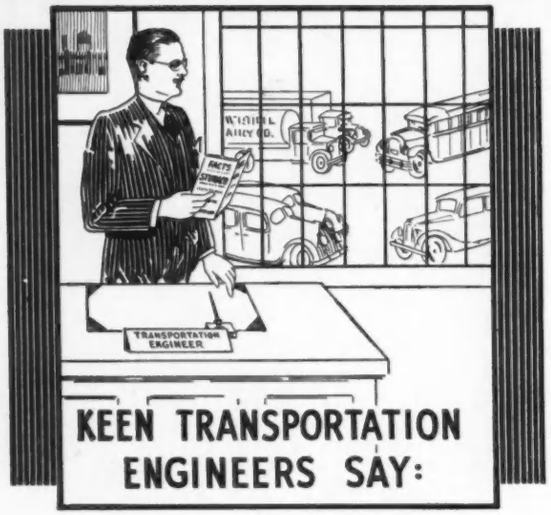
This year was the busiest in Borg and Beck history. We go into 1936 with a new volume record—over 1,000,000 clutches produced and delivered for the 1935 cars—and with our clutches listed as standard equipment on 37 of today's new passenger and commercial cars. • Such a record did not come to us through super-salesmanship, or as a gesture of good fellowship from automotive engineers. We do have cherished friendships among the automotive engineers and manufacturers, but we never forget that Borg and Beck clutches would be kicked out in the cold if we didn't build, and keep on building the best clutches money can buy. • That's just as it should be. That's what keep us on our toes—everlastingly striving to make the quality, the mechanical fitness and the durability of our clutch so nearly perfect that car owners are only vaguely aware that there is one in the car.

THE BORG & BECK COMPANY

Division of Borg-Warner Corporation

CHICAGO, ILLINOIS

"STURACO"
★★★★
EXTREME PRESSURE ("E.P.")
GEAR AND CHASSIS LUBRICANTS



KEEN TRANSPORTATION ENGINEERS SAY:

" . . . the size of the gears has been reduced and the speed and power output have been increased to such an extent that EP lubricants . . . are coming into more general use."

" . . . both the mild EP and the powerful EP lubricants are of real commercial importance at the present time."

When gear and bearing failures are occurring too frequently, a change to "STURACO" frequently proves a practical and economical remedy. Investigate this low cost "Insurance policy" by writing for Bulletin No. 4.

"STURACO" E. P. LUBRICANTS
ARE THE ORIGINAL DEVELOPMENT OF
D. A. STUART & CO.
ESTABLISHED 1865
GENERAL OFFICES, 2727-2753 SO. TROY ST. CHICAGO, U.S.A.
BRANCHES IN PRINCIPAL CITIES

Notes and Reviews

THESE items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Conceptions Modernes sur le Vol Animal

By R.-S. Lacape. Published in *L'Aéronautique*, July, 1935, L'Aérotechnique section, p. 61. [A-1]

A summary is here given of lectures on animal flight given by the investigator Dr. A. Magnam at the College of France during 1935. In the analysis given, the flight characteristics of a considerable number of birds and insects are presented.

Les Problémes de l'Aviation Stratosphérique

By Rougeron. Published in *L'Aéronautique*, July, 1935, p 187. [A-1]

Asserting his belief that the internal-combustion engine in its present form is capable of being adapted to stratospheric flight, the author states that the principal problem to be solved in such adaptation is cooling. In a series of articles he proposes to seek out the path toward cooling systems offering distinctly less drag than those at present in use.

Dynamik des Schwingenfluges

By W. Schmeidler. Published in *Luftfahrtforschung*, July 30, 1935, p. 128. [A-1]

To develop, through mathematical analysis, knowledge on the forces involved in the operation of flapping-wing type aircraft is the object of this article. Formulas for the lift and thrust of a flapping-wing system are worked out, and these were confirmed by model tests. The aerodynamic forces involved in the operation of such a system and its efficiency are studied. Finally, a systematic method for the design of a flapping-wing type aircraft is presented.

Über die Leistungsvermindernde Wirkung von Auspuffgasen auf Flugzeugbesatzungen und über Kohlenoxydmessungen in Verschiedenen Flugzeugmustern

By S. Ruff. Published in *Luftfahrtforschung*, July 30, 1935, p. 124. [A-4]

After discussing the deleterious effects on occupants of airplanes of breathing exhaust gas fumes, the article reports results of measurements of carbon monoxide concentration in the air of 5 different aircraft under different flight conditions. The concentrations found exceeded the maximum allowable, but were reduced to that figure by means of exhaust manifolding.

Le Dispositif Gianoli de Pilotage Automatique

By Marcel Gianoli. Published in *L'Aéronautique*, June, 1935, p. 163. [A-4]

The automatic piloting system here described has been adopted in part by the French government and is about to be produced on a commercial basis.

La Protection Collective de la Population Civile contre les Attaques Aériennes en France et à l'Étranger

By L. Faivre. Published in *Le Génie Civil*, August 3, p. 110 and August 10, 1935, p. 130. [A-4]

That the danger of an aerial attack in warfare is not only real, but great, is the author's opinion. He refers to a law passed in France, April 8, 1935, which makes obligatory the organization throughout the country of passive defense for the civilian population against such attack. In the first part of his article he sets forth the administrative and legal measures taken in France, Italy and Germany for the organization of this type of defense, and in the second he describes the means employed to put these measures into effect.

(Continued on page 36)

HARRISON

RADIATORS • RADIATORS • RADIATORS

CAR HEATERS CAR HEATERS

THERMOSTATS THERMOSTATS

OIL TEMPERATURE REGULATORS OIL TEMPERATURE REGULATORS

RADIATORS RADIATORS

CAR HEATERS CAR HEATERS

THERMOSTATS • THERMOSTATS • THERMOSTATS

OIL TEMPERATURE REGULATORS • OIL TEMPERATURE REGULATORS

25th Anniversary

Harrison history is a record of progress . . . of constantly improved design, engineering and manufacturing methods. Harrison's position as the world's largest manufacturer of radiators, thermostats, car heaters and oil temperature regulators is a direct result of the dependable service which Harrison products have given on millions of passenger cars and trucks.

HARRISON RADIATOR CORPORATION

LOCKPORT, NEW YORK

FLEX-O-TUBE

The Automotive Industry's standard
FLEXIBLE FEED LINES
for
Gasoline, Oil or Grease

Our years of experience in the manufacture of automotive flexible feed lines have definitely established this product as the safest and most reliable.

The common-sense construction of FLEX-O-TUBE with the flexible *metallic* inner tube combined with a flexible *non-metallic* cover has made this the choice of automotive engineers everywhere.

AVOID IMITATIONS

INSIST ON GENUINE

FLEX-O-TUBE

THE FLEX-O-TUBE CO.

DETROIT, MICH.

NOTES AND REVIEWS

Continued

MATERIAL

A Short Account of the Theory of Lubrication—Introduction: Viscosity and Friction

By Mayo Dyer Hersey. Published in the *Journal of The Franklin Institute*, June, 1935, p. 677. [G-1]

This article deals with fundamental concepts, first reviewing briefly the history of lubrication, and then discussing mathematically the relation of viscosity to frictional resistance. The classical form of the hydrodynamic theory, dimensional theory, and the thermodynamics of lubrication are to be taken up successively in three installments to follow.

Oil Volatility Directly Related to Oil Consumption

By L. L. Davis and R. D. Best. Published in *National Petroleum News*, June 26, 1935, p. 70. [G-1]

The authors point out that there is an economic need for determining the effect of the volatility on consumption in order to conserve the supply of neutral oils which are in great demand for blending purposes in the effort to reduce oil consumption. They conceived the possibility of isolating the effect of volatility by preparing a series of oils in which that was the only variable. The tests are described and the following conclusions drawn:

(a) The effect of volatility as compared to viscosity on oil consumption appears greater than previously thought, particularly in cases of high-temperature operation where the basic consumption is low;

(b) The effect of volatility on consumption is of minor importance when the consumption is very high because of engine design or high speed;

(c) In a given uniform series of oil from the same source there is a simple relationship between front end volatility and consumption;

(d) In an unrelated or non-uniform series of oils the volatility effect may be a function of the front end volatility modified by the over-all distillation characteristics.

This paper was presented before the American Society for Testing Materials, Detroit, June 24 to 28, 1935.

Are Metals Permeable by Oil?

By Augustus H. Gill. Published in *Mechanical Engineering*, July, 1935, p. 413. [G-1]

Reference is made to the research and methods used by Woodbury, and Conradson and Duguid and tests conducted at the Massachusetts Institute of Technology are described. The author explains that whereas Woodbury washed the old oil out of the bronze with the new, and Conradson and Duguid actually squeezed the oil out of babbitt and bronze under pressure, he has obtained the oil by another process—actual extraction of the bronze chips with solvents.

From these experiments it appears that leaded bronze will absorb about 0.3 per cent of oil, and that it penetrates at least 0.375 in. Mild steel did not absorb oil.

Light Metals and Their Alloys

By William M. Corse. Published in *Industrial and Engineering Chemistry*, July, 1935, p. 745. [G-1]

Mr. Corse reviews the history of the development of light metals and points out the individual characteristics of aluminum and its various alloys which determine the applications of each.

La Technique des Alliages Légers de Fonderie; Leurs Applications dans l'Automobile

By A. Dumas. Published in *Journal de la Societe des Ingénieurs de l'Automobile*, April-May, 1935, p. 199. [G-1]

Physical and mechanical advantages in addition to mere lightness have instigated the recent increasing use of aluminum alloys, says the author, chief engineer of "Aluminum Français". Thermal conductivity and ease of machining are two of the qualities emphasized in the discussion, which deals principally with cast aluminums. The chemical composition and physical properties of such aluminums in general are given, as well as those, in particular, of aluminums used for pistons, crankcases, cylinder heads, rear axles, brake drums and miscellaneous engine and body parts.

Kraftfahrzeugfertigung im Lichte der Rohstofffreiheit

By Erich Gründger. Published in *Automobiltechnische Zeitschrift*, June 25, 1935, p. 293. [G-1]

The effect on the automotive manufacturer of the German edict of April 24, 1935, forbidding the use of certain metals for certain purposes is discussed. In this and subsequent articles, substitute metals are suggested, the possibilities of aluminum alloys and steel being particularly emphasized.

(Concluded on page 38)

"I'M A telephone installer and I like to be busy. A good many people are calling up these days and saying they would like to have a telephone put in.

"Often they will make an appointment and it's my job to be there on the dot. The company is a stickler for that. More than 97% of the appointments made with subscribers are now met at the exact time requested. We're trying to do even better than that.

"Seems to me it's something worth while—putting in a telephone. People always seem happier when I tell them they are connected and everything is O.K. Especially if they have been without the telephone for a little while. Most everybody says the same thing—'We missed it.'

"Well, I hope it keeps up. It means a lot to have a telephone in the house and it means a lot to us fellows who work for the telephone company."

The Bell System employs a total of 270,000 *men and women. They are your friends and neighbors. Good business for the telephone company is a sign of prosperity in the country.*

BELL TELEPHONE SYSTEM

WORKS AS *Effortless* AROUND CORNERS . . .

. . . AS IT DOES ON THE STRAIGHT-AWAYS!

Manual control must work freely and effortless—yet must stay put! It must work around corners as reliably as it does on the straightaway—and do so without binding or kinking! . . . Tru-Lay Push-Pull is the ideal manual control for brakes, throttle control (including those for rear engines), over-speed controls on transmissions and axles, etc. . . . The design of Push-Pull insures its efficiency. It consists of Tru-Lay Preformed Cable encased in a spiral, non-compressible steel covering tightly processed over the cable. This assembly is enclosed in a water and grease-tight flexible housing. . . . The armored strand works freely in a bath of grease. It is rattle-proof, requires no adjustment and is free of toggles, rods, pins and cotters. Once installed, its efficiency and usefulness is unlimited. . . . Consult with American Cable engineers as to how you can adapt Push-Pull to your control problems.

AMERICAN CABLE COMPANY
General Motors Building, Detroit, Michigan
An Associate Company of the American Chain Company, *Inc.*
Manufacturers of the famous
WEED TIRE CHAINS

TRU·LAY PUSH→ ←PULL CONTROLS

NOTES AND REVIEWS

Concluded

MISCELLANEOUS

L'Autorail Léger et Rapide

By André Mercier. Published in *Le Génie Civil*, August 17, 1935, p. 149. [H-1]

In attaining the second stage of its development, utilization for principal as well as for auxiliary lines, the railcar has until recently steadily taken on increased weight. Present trends are toward a vehicle that shall be light and durable as well as capable of high-speed operation. This article describes in detail and gives performance figures of an example of such development.

PASSENGER CAR

La T.S.F. et l'Auto

By Marc Chauvierre. Published in *Journal de la Société des Ingénieurs de l'Automobile*, April-May, 1935, p. 209. [L-1]

The radio receiver is destined to become an accessory necessary for the completion of an automobile is the author's conclusion to his discussion, in which he treats of the adaptions necessary in a conventional receiver and in a conventional car in order that the two may operate harmoniously. He describes two automotive radio sets, one manufactured in Holland and one in the United States, and urges French manufacturers to furnish a domestic product, hitherto lacking.

Les Nouveautés Mécaniques dans les Véhicules de Tourisme

By C. Martinot-Lagarde. Published in *La Technique Moderne*, August 15, 1935, p. 540. [L-1]

The automobile for individual transport, used more often for work than for pleasure, is undergoing a profound transformation tending toward increased riding-comfort and automaticity of operation, with increased mechanical complication as a corollary. Thus summarizing automotive development of the last few years, the author describes the new design features introduced during that time that have survived the test of practicability.

DETROIT'S SHOW PLACE

Book-Cadillac is headquarters for Automobile Show-Goers

1200 beautiful rooms ($3.00 and up). Four inviting restaurants, serving renowned food. Oak-paneled English Grill—with all the luxury of a downtown club. Gay music in the merry Mayfair Room. Tinkling drinks in the smart Cocktail Lounge. No wonder the "Book" is Detroit's official *show* place.

Book-Cadillac Hotel
1200 Rooms from $3.00
J. E. Frawley, General Manager
Directed by National Hotel Management Co., Inc.
Ralph Hitz, President